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NERVOUS SYSTEM OF THE ECHINODERMATA.

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THE Editors of 'BRAIN' having requested me to supply an abstract of the research which Professor Ewart and myself are at present conducting on the locomotor system of the echinodermata, I think that their wishes will best be met by restricting the abstract to those features of the research which have special reference to the morphology and physiology of the nervous system.

Morphologically, then, the nervous system of the echinodermata is constructed on a simple plan. Taking the common star-fish as a type, it is generally known that the nervous system consists of a pentagonal ring of ganglia and fibres surrounding the mouth, and sending off a trunk into each ray, which supplies numberless branches to the muscles and ambulacral feet, or pedicels. Choosing the echinus, or sea-urchin, for a more detailed account of the character and distribution of the nervous system, we find that it is composed of two parts —one internal and the other external to the shell. The internal part consists of fine radial trunks, which may be traced from the ocular plates along the ambulacral areas external to the radial canals to the oral floor, where they bifurcate and unite with each other, so as to form a pentagonal nerve-ring. This ring lies between the œsophagus and the

tips of the teeth which project from the lantern. Small branches leave the ring and supply the œsophagus, and lateral branches arise from the several trunks to escape with the pedicels through the apertures of the pore plates. Each trunk lies in a sinus situated between the lining membrane of the shell and the ambulacral radial canal; the lateral branches which accompany the first series of pedicels through the oral floor are large and deeply pigmented; the branches within the auricles are small; those external to the auricles gradually increase in size until the equator is reached, and from the equator to the ocular plates they diminish. At the equator the trunk is wider than at either pole, and it is often partially divided for some distance at each side of the equator by a deep longitudinal fissure. When the nerve trunk, after being stained with chloride of gold or with osmic acid, is removed from its sinus, it is seen to be enveloped by a thin fibrous sheath. This sheath contains numerous large pigment cells, and has scattered over it irregular masses of protoplasm which have been deposited from the fluid of the neural sinus.

When the sheath is removed the trunk is seen to consist of delicate fibres and of fusiform cells; the cells consist of a nucleus and a thin layer of protoplasm which projects at each end and terminates in a nerve-fibre.

The lateral branches of the trunk escape along with, and are partly distributed to, the pedicels; the remainder breaks up into delicate filaments which radiate from the base of the pedicel under the surface epithelium. When one of the large branches already referred to as escaping with the inner row of pedicels is traced through the oral floor after sending a branch to the foot, it breaks up into delicate fibres, some of which run towards the bases of the adjacent spines and pedicellariæ, while others run inwards a short distance towards the oral aperture.

Either in connection with, or anatomically independent of these filaments from the lateral branches of the nerve trunks, there is an external plexus lying almost immediately under the surface epithelium and extending from the shell to the spines and pedicellariæ. The fibres of this plexus closely resemble those of the lateral branches of the trunk; but generally they

are smaller in size and have a distinct connexion with nerve cells. The cells consist of an oval nucleus and of a layer of protoplasm, which is generally seen to project in two, or sometimes in three, directions—the several processes often uniting with similar processes from adjacent cells so as to form a fibro-cellular chain or network.

In preparations from portions of Echini treated with both chloride of gold and osmic acid, we have succeeded in tracing the plexus over the surface of the shell between the spines and pedicellariæ; and from the surface of the shell to the capsular muscles at the bases of the spines. Further, we repeatedly observed delicate fibres passing beyond the muscles, apparently to end under the epithelium over the surface of the spines.

In the case of the pedicellariæ, the plexus on reaching the stem runs along between the calcareous axis and the surface epithelium, to reach and extend over and between the muscular and connective tissue-fibres between the calcareous axis and the bases of the mandibles. The plexus, now in the form of exceedingly delicate fibres connecting small bipolar cells, reaches the special muscles of the mandibles. In several preparations, delicate fibres appeared to extend towards the sensitive epithelial pad situated on the inner surface of each mandible, a short distance from the apex. Although this plexus is especially related to the muscular fibres—lying over and dipping in between them—it is also related to the surface epithelium, and delicate fibres often extend from it to end under or between the epithelial cells.

Before proceeding to give an account of the physiology of the nervous system, it is desirable to say a few words on the natural movements of star-fishes and sea-urchins. This is desirable, not only because it is necessary to study the natural movements before we can be in a position to appreciate the results of the following experiments, but also because these natural movements form in themselves a study of considerable interest.

Taking the common star-fish (*Uraster rubens*) as our starting-point, it is needless to dwell upon the well-known mechanism of the ambulacral system. The rate of crawling upon a flat horizontal surface is 2 inches per minute. The animal usually

crawls in a determinate direction, and, while crawling, the ambulacral feet at the end of each ray are protruded forwards as feelers; this is particularly the case with the terminal feet on the ray, or rays, facing the direction of advance. When in the course of their advance these tentacular feet happen to come into contact with a solid body, the animal may either continue its direction of advance unchanged, or may deflect that direction towards the solid body. Thus, for instance, if, while the star-fish is advancing along the floor of a tank, the tentacular feet at the end of one of its rays happen to touch a perpendicular side of the tank, the animal may either at once proceed to ascend this perpendicular side, or it may continue to progress along the floor—feeling the perpendicular side with the ends of its rays perhaps the whole way round the tank, and yet not choosing,[1] as it were, to ascend. What it is that determines the animal in some cases to ascend, and in other cases not, we were unable to ascertain.

When a star-fish ascends the perpendicular side of a tank or bell-jar till it reaches the surface of the water, it very frequently performs a number of peculiar movements, which we may call acrobatic. On reaching the surface of the water, the

[1] It may be as well to explain that in using such words as these, I do not, in the present paper, attach to them any psychological signification; they are used as merely metaphorical terms which serve most briefly, and therefore most conveniently, to express the resultants of those systems of physiological stimuli, the composing members of which we were not able to observe. When one star-fish appears to choose to ascend the side of a tank, while another star-fish, under apparently precisely similar circumstances as to stimulation, seems to prefer walking along the floor, we can only suppose that the circumstances of stimulation, although apparently similar, are not really so, and therefore that the difference in the result is due to some difference in the stimulation. Of course it may be objected to this that the same remark applies to cases in which the psychological element unquestionably enters—choice on its physiological side being merely the resultant of some unobservable system of stimuli. But without here entering on the whole question of the relation between body and mind, it is enough to point out that the only evidence we can have of a physiological determination presenting a psychological side, is by observing that the organism which exhibits the determination is capable of altering it on future occasions, if the determination first made is found by individual experience to be injurious. In other words, the power of learning by individual experience is the only unequivocal evidence we can possess of the presence, in any animal, of a psychological element; and as we have observed no such evidence in the case of any of the echinoderms, we desire it to be understood that we consider all their movements to be of the so-called "reflex" kind.

animal does not wish to leave its native element, and neither does it wish again to descend into the levels from which it has just ascended. It therefore begins to crawl to one side or the other, and while crawling it every now and then throws back its uppermost ray, or rays, to feel for any solid support that may happen to be within reach. The distance to which the rays may thus be thrown back is remarkable; for the animal may hold on with its two lower rays alone, or even with the end of a single ray, and throw back the whole of the other rays with the central disc into a horizontal position—the ambulacral surface of the rays which are thrown back being then of course turned up, so as to face the surface of the water. If the rays succeed in finding a solid body, they will perhaps —though not necessarily—fasten upon it, and when their hold is secure, the rays which hitherto held the animal to the side of the tank relax their suckers, so that the star-fish swings from its old to its new surface of attachment. The activity and co-ordination which the rays manifest in executing these various acrobatic movements is surprising, and give to the animal an almost intelligent appearance.

With slight modifications this description may be taken to apply to all the other species of echinoderms (except *Holothuria*) which we have observed. These modifications are as follows:—

(i) There is a kind of star-fish (*Astrðpecten aurantiacus*) the ambulacral feet of which have lost their terminal suckers—these being but rudimentary, and the ambulacral feet being therefore pointed tubes. The animal uses these tubes in walking along a flat horizontal surface by pointing all the feet of all the rays in the direction of advance, and then distending them with fluid; they thus become so many pillars of support. The fluid is then suddenly withdrawn, and the star-fish falls forward with a jerk. It is particularly noteworthy that in this mode of progression all the feet of all the rays are co-ordinated in their action for determining one definite direction of advance—those in the ray facing that direction acting forwards, or centrifugally, those in the hinder rays backwards, or centripetally, and those in the lateral rays sideways. This description applies to the animal when progressing on a flat

horizontal surface out of the water; when in the water it appears as if the feet, besides being used as walking poles in the manner just described, are also used to sweep backwards along the floor of the tank, and so to assist in propelling the animal forwards after the manner of cilia. The result of all these movements is to produce a kind of locomotion which would seem more suited to a centipede than to a star-fish, and it enables the animal to travel at a surprising rate—i.e. from one to two feet per minute.

(ii) Brittle-stars (*Ophiuridiæ*) have entirely lost their ambulacral suckers, and the ambulacral feet themselves have become so rudimentary that they are functionally useless. Progression is therefore here effected entirely by the muscular contractions of the rays—the latter alternately shooting themselves forward and curving themselves backwards upon the floor of the tank like the arms of a swimming man—the resulting friction on the floor of the tank causing the animal to advance. This it does with great rapidity—viz. six feet per minute.

(iii) *Echini*, among echinoderms, stand at the opposite end of the series from the brittle-stars with reference to the solidarity of their rays, for these are here all united in a rigid box-like shell. Consequently the rate of their locomotion stands in striking contrast with that of the brittle-stars, being only six inches, instead of six feet, per minute. Looking to the slowness of this rate of locomotion, it must strike us as a curious fact that there is, perhaps, no animal which can properly be said to approach the *Echinus* in respect of the number and elaboration of special mechanisms subservient to the function of locomotion. Careful observation has satisfied us that these special mechanisms are four in number, and each of these displays an immense amount of elaboration. They are the pedicels, which act in the same way as they do in the star-fish, though with more adhesive power; the spines, which by closely co-ordinated movement act as walking poles; the lantern, which by alternate protrusion and retraction, does the same; and the pedicellariæ, which snap at pieces of seaweed and hold them steady till the suckers of the pedicels have time to form their adhesions.

From this account of the natural movements exhibited by

the several groups of echinodermata here considered, it may be observed that we have presented to our view an interesting series of graduated modifications. At one end of this series we have *Echinus* and *Spatangus* with their rays all united into a box-like rigid shell. At the other end of the series we have the brittle-stars with their muscular rays, highly mobile, and indeed snake-like in their well co-ordinated movements. Midway in the series we have the sea-cucumber and common star-fish, where the body is flexible and mobile, though not so much so as in the brittle-stars. Now, the interesting point to observe is, that in correlation with this graduated difference in the function of the rays, we have a correspondingly graduated difference in the development of the ambulacral system. In *Echinus* and *Spatangus* this system is seen in its most elaborate and efficient form—in *Echinus* the pedicels, spines, and pedicellariæ being more highly developed and useful than in any of the other groups, except *Spatangus*, where the spines are even more so. In the common star-fish, sun-stars, and sea-cucumbers, the ambulacral feet are still the most important organs of locomotion, although even here we begin to see that the development of the general muscular system has begun to tell upon that of these specially locomotor organs. Again, in *Astropecten* the still greater development of the general muscular system has told still further upon that of the ambulacral feet, the terminal suckers having become aborted. Lastly, the brittle-stars have altogether discarded the use of their ambulacral feet in favour of the much more efficient organs of locomotion supplied by their muscular rays; and not only the terminal suckers of these feet, but even the whole of the feet themselves, have dwindled into useless rudiments.

Lastly, with reference to natural movements, all the echinodermata that we have observed are able, when placed upon their dorsal surfaces on the floor of a tank, to recover their normal position on their oral surface. The common star-fish does so by twisting the ends of two or more of its rays round, so as to bring its terminal suckers into action upon the floor of the tank, and then, by a successive and similar action of the suckers further back in the series, the whole ray is progressively twisted round, so that its ambulacral surface is applied

flat against the floor. The rays which perform this action twist their semi-spirals in the same direction, and by their concerted action serve to drag the disc and the remaining rays over themselves as a fulcrum. Other species of star-fish, which have not their ambulacral suckers sufficiently developed to act in this way, execute their righting movements by doubling under two or three of their adjacent rays, and turning a somersault over them, as in the previous case. *Echinus* rights itself when placed on its ab-oral pole, by the successive action of two or three adjacent rows of suckers—so gradually rising from ab-oral pole to equator, and then as gradually falling from equator to oral pole. *Spatangus* executes a similar manœuvre entirely by the successive pushing and propping action of its longer spines.

Coming now to our experiments on the physiology of the nervous system, I may conveniently divide them into two classes—those in stimulation and those in section.

All the echinoderms we have observed respond to all kinds of stimulation. The period of latency varies considerably in different species, and in different parts of the same animal. In the holothurians it is remarkably long, and from the seat of stimulation there very frequently starts a wave of strong contraction, which passes with extreme slowness throughout the length of the animal in the form of a deep constriction. Similar waves frequently occur spontaneously.

All the echinoderms seek to escape from injury. Thus, for instance, if a star-fish or *Echinus* is advancing continuously in one direction, and if it be pricked or cut in any part of an excitable surface facing the direction of advance, the animal immediately reverses that direction; or, if it be taken out of the water and a drop of some irritating fluid be placed on any part of the external surface, the animal will endeavour to move away from the source of irritation; whether placed upon a dry table or returned to the water, the echinoderm will at once strike off in a perfectly straight line from the source of irritation, and for a long time will travel much more rapidly than usual. When two points of the surface are thus irritated, the direction of advance is usually the diagonal between them. When a greater number of points are irritated, the direction

of advance becomes uncertain, but if any, even short, interval of time is allowed to elapse between the application of successive stimuli to different parts of the surface, the direction of advance will be in a straight line from the stimulus applied latest. When a star-fish is fastened upon a perpendicular surface, and any part of its body is irritated, as, e.g., by a nip with the forceps, the animal, if a sun-star, will actively run away from the irritation. If, however, the latter be followed up and repeated, the star-fish seems to make up its mind to escape in a still more expeditious manner, for it immediately lets go its hold with all its suckers, and falls to the bottom of the water. A common star-fish will generally resort to this method when first irritated, without waiting for a repetition of the stimulus. An *Echinus*, on the other hand, will not drop off a perpendicular surface unless compelled to do so by serious irritation; it crawls away as quickly as possible, and sometimes rotates upon its axis in a manner afterwards to be described, whereby, without leaving go its hold of the perpendicular surface, it is able to alter its position rapidly. But of all the echinoderms the most curious to observe in this connection are the brittle-stars, for these may be made to leap about in any number of directions with much activity, by gently stimulating different parts of their bodies successively. When any part of the dorsal surface of any star-fish is irritated, not unfrequently one of the arms is doubled over and touches the seat of irritation, as if to endeavour to brush away the offending body.

That the external surface of a star-fish should prove itself to be excitable is what we should perhaps expect *à priori*, although we might not expect to find so high a degree of co-ordination manifested by the nervous system as is implied by its responses to the cutaneous excitations above mentioned. But that the external surface of an *Echinus* or *Spatangus* should be so highly excitable as it is, we should scarcely have anticipated—particularly before our observation of the external nervous plexus; for at first sight it would seem that the numberless long and mobile feet—to say nothing of the spines—would be sufficient to convey all the information that the animal requires concerning the external world, without its

exterior requiring to be rendered sensitive over its whole surface. Yet we find, so far is this from being the case, that the external surface cannot be touched with a needle's point at any part without the whole animal being affected thereby. We have already described the nervous plexus whereby this general sensitiveness of the external surface is secured. We must now enter pretty fully into the functions of this plexus as revealed by sundry experiments on the multitudinous and wonderful system of organs which, either directly or indirectly, depend upon this plexus for their innervation.

These organs are the ambulacral feet, the spines, and the pedicellariæ. That all these organs are in nervous connection with the external plexus is proved by the fact that when any part of the external surface is touched, however gently, all the feet, spines, and pedicellariæ within reach of that point, and even far beyond, immediately approximate and close in upon the point, so holding fast to the needle, or whatever other body may be used as the instrument of stimulation. This simultaneous movement of such a little forest of prehensile organs is a singularly beautiful spectacle to witness. In executing it, the pedicellariæ are much the most active, the spines somewhat slower, and the ambulacral feet very much slower. If the object with which the external surface is touched be itself small enough, or presents edges narrow enough, to admit of the forceps on the pedicellariæ establishing a hold upon it, it is seen to be immediately seized by some of these organs, and held there till the spines and ambulacral feet come up to assist; but if the object is too large, or does not present any surfaces which the pedicellariæ are able to catch—such, for instance, as the point of a pencil—the spines alone are able to hold it with wonderful firmness by forcing their tips against it on all sides.

The area thus affected by an ordinary stimulation, such as that supplied by a touch with a needle, measures in a longitudinal direction about half an inch. The extent of the area affected in a transverse or latitudinal direction depends upon the point stimulated with reference to the ambulacral feet. Midway in an interambulacral area the influence extends as far as the double rows of feet on either side; the feet, however,

of the inner, or nearer rows, moving more decidedly than those of the outer, or further, rows. The spines are rarely affected beyond the area named by a stimulus of mere contact, but in the case of the pedicellariæ the irradiation of the stimulating influence may proceed further, sometimes extending as far as the second double row of feet, or ambulacral area, on either side; the certainty and activity of their movements, however, rapidly diminish with their distance from the seat of stimulation. At and near the seat of stimulation, i.e., within the area first named, the certainty and activity of their movements are very great, and the period of latency very short; in other words, immediately any solid body touches any part of the external surface of an *Echinus*, it is surrounded by all the pedicellariæ in the neighbourhood, while even those which are too far away to touch the object will, perhaps for the long distance round which we have named, bend towards it.

And here we have the proof of the function of the pedicellariæ. In climbing perpendicular or inclined surfaces of rock, covered with waving sea-weeds, it must be of no small advantage to an *Echinus* to be provided on all sides with a multitude of forceps, all mounted on movable stalks, which instantaneously bring their grasping forceps to bear upon and to seize a passing frond. The frond being thus arrested, the spines come to the assistance of the pedicellariæ, and both together hold the *Echinus* to the support furnished by the sea-weed. Moreover the sea-weed is thus held steady till the ambulacral feet have time also to establish their hold upon it with their sucking discs. That the grasping and arresting of fronds of sea-weed in this way for the purposes of locomotion constitute an important function of the pedicellariæ, may at once be rendered evident experimentally by drawing a piece of sea-weed over the surface of a healthy *Echinus* in the water. The moment the sea-weed touches the surface of the animal, it is seen and felt to be seized by a number of these little grasping organs, and—unless torn away by a greater force than is likely to occur in currents below the surface of the sea—it is held steady till the ambulacral suckers have time to establish their attachments upon it. Thus there is no doubt that the pedicellariæ are able efficiently to perform the function which we

regard as their chief function. We so regard this function, not merely because it is the one that we observe these organs chiefly to perform, but also because we find that their whole physiology is adapted to its performance. Thus their multitudinous number and ubiquitous situation all over the external surface of the animal, are suggestive of their being adapted to catch something which may come upon them from any side, and which may have strings and edges so fine as to admit of being enclosed by the forceps. Again, the instantaneous activity with which they all close round and seize a moving body of a size that admits of their seizing it, is suggestive of the objects which they are adapted to seize being objects which rapidly brush over the surface of the shell, and therefore objects which, if they are to be seized at all, must be seized instantaneously. Lastly, we find, on experimenting upon pedicellariæ whether *in situ* or when separated from the *Echinus*, that the clasping action of the forceps is precisely adapted to the function which we are considering; for not only is the force exerted by the forceps during their contraction of an astonishing amount for the size of the organ (the serrated mandibles of the trident pedicellariæ holding on with a tenacity that can only have reference to some objects liable to be dragged away from their grasp), but it is very suggestive that this wonderfully tenacious hold is spontaneously relaxed after a minute or two. That is to say, the pedicellariæ tightly fix the object which they have caught for a time sufficient to enable the ambulacral suckers to establish their connections with it, and then they spontaneously leave go; their grasp is not only so exceedingly powerful while it lasts, but it is as a rule timed to suit the requirements of the pedicels.

We must next consider stimulation with reference to the spines. It has already been said that these organs co-operate with the pedicellariæ in grasping any instrument of stimulation, and this proves that for a certain area round any seat of stimulation the spines admit of co-ordinated action. Further experiments prove that there is no limit to the area within which co-ordinated action of the spines may take place; but that all the spines of the organism may work together to the attainment of some common end. Thus it has already been

stated in a previous part of this paper that a *Spatangus*, when placed upon its back, is able to right itself by the co-ordinated action of its spines alone; and also that an *Echinus*, when taken out of the water and placed upon a table, will walk in a determinate direction by the same means. The very complete co-ordination of the spines implied by these facts is, however, rendered still more conspicuous by experiments in stimulation; for if, while an *Echinus* is walking on the table in the manner just alluded to, a scrape with a scalpel, a drop of spirit, a lighted match, or any other severe stimulus be applied at some one part of the animal's exterior, the spines all over the surface begin to take on an active bristling movement, and the direction of advance is immediately changed into a straight line of escape from the source of injury. And, were it necessary, other experiments could be detailed to show that the multitudinous spines of an *Echinus* are as closely co-ordinated in their action as so many limbs.

It remains to consider stimulation with reference to the pedicels. Taking here the star-fish as a type of the echinodermata, the results of our experiments on this head, and so far as stimulation is concerned, are as follows. When a drop of acid, or other severe stimulation is applied to any part of a row of protruded pedicels, that whole row is immediately retracted, the pedicels retracting successively from the seat of irritation—so that if the latter be in the middle point of the series, two series of retractions are started, proceeding in opposite directions simultaneously; the rate at which they travel is rather slow. This process of retraction, however, although so complete within the ray irritated, does not extend to the other rays. But if the stimulus be applied to the centre of the disc, upon the oral surface of the animal, all the feet in all the rays are more or less retracted—the process of retraction radiating serially from the centre of stimulation. The influence of the stimulus, however, diminishes perceptibly with the distance from the centre; thus, if weak acid be used as the irritant, it is only the feet near the bases of the rays that are retracted; and, even if very strong acid be so used, it is only the feet as far as one-half or two-thirds of the way up the rays that are fully retracted—the remainder only having their

activity impaired, while those near the tip may not be affected at all. If the drop of acid be placed on the dorsal, instead of the ventral surface of the disc, the effect on the feet is found to be just the converse; that is, the stimulus here applied greatly increases the activity of the feet. Further experiments show that this effect is produced by a stimulus applied anywhere over the dorsal aspect of the animal; so that, for instance, if a drop of acid be placed on the skin, at the edge of a ray, and therefore just external to the row of ambulacral feet, the latter will be stimulated into increased activity; whereas, if the drop of acid had been placed a very small distance past the edge of the ray, so as to touch some of the feet themselves, then the whole row would have been drawn in. We have here rather an interesting case of antagonism, which is particularly well marked in *Astropecten*, on account of the active writhing movements which the feet exhibit when stimulated by an irritant placed on the dorsal surface of the animal. It may be added that in this antagonism the inhibitory function is the stronger; for when the feet are in active motion, owing to an irritant acting on the dorsal surface, they may be reduced to immediate quiescence—i.e., retracted—by placing another irritant on the ventral surface of the disc. Similarly, if retraction has been produced by placing the irritant on the ventral surface of the disc, activity cannot be again induced by placing another drop of the irritant on the dorsal surface.

The only other observations that need be mentioned under the heading of stimulation are those which refer to the influence of light. We have found unequivocal evidence of the star-fish (with the exception of the brittle-stars) and the *Echini* manifesting a strong disposition to crawl towards, and to remain in, the light. Thus if a large tank be completely darkened, except at one end where a narrow slit of light is admitted, and if a number of star-fish and *Echini* be scattered over the floor of the tank, in a few hours the whole number, with the exception of perhaps a few per cent., will be found congregated in the narrow slit of light. The source we used was diffused daylight, which was admitted through two sheets of glass, so that the thermal rays might be considered prac-

tically excluded. The *intensity* of the light which the echinoderms are able to perceive may be very feeble indeed; for in our first experiments we boarded up the face of the tank with ordinary pine-wood, in order to exclude the light over all parts of the tank except at one narrow slit between two of the boards. On taking down the boards we found indeed the majority of the specimens in or near the slit of light; but we also found a number of other specimens gathering all the way along the glass face of the tank that was immediately behind the pine-boards. On repeating the experiment with blackened boards, this was never found to be the case; so there can be no doubt that in the first experiments the animals were attracted by the faint glimmer of the white boards, as illuminated by the very small amount of light scattered from the narrow slit through a tank all the other sides of which were black slate. Indeed, towards the end of the tank, where some of the specimens were found, so feeble must have been the intensity of this glimmer, that we doubt whether even human eyes could have descried it very distinctly. Owing to the prisms at our command not having sufficient dispersive power for the experiments, and not wishing to rely on the uncertain method of employing coloured glass, we were unable to ascertain how the echinoderms might be affected by different rays.

On removing with a pointed scalpel the eye-spots from a number of star-fishes and Echini without otherwise injuring the animals, the latter no longer crawled towards the light, even though this were admitted to the tank in abundance; but they crawled promiscuously in all directions. On the other hand, if only one of the five eye-spots were left intact, the animals crawled toward the light as before.

Coming now to the experiments in section, we find that single rays detached from star-fish crawl as fast and in as determinate a direction as do the entire animals. They also crawl towards the light, up perpendicular surfaces, and sometimes away from injuries; but they do not invariably, or even generally, seek to escape from the latter, as is so certain to be the case with entire animals. Lastly, separated rays right themselves when inverted as quickly as do the unmutilated organisms.

Removing the tip of a severed ray does not impair any of these movements, except, of course, the crawling towards light, which it completely destroys. Dividing the nerve in any part of its length has the effect, whether or not the ray is detached from the animal, of completely destroying all physiological continuity between the feet on either side of the line of division. Thus, for instance, if the nerve be cut across half-way up its length, the row of feet is at once physiologically bisected—one-half of the row becoming as independent of the other half as it would were the whole ray divided into two parts. That is to say, the distal half of the feet may crawl while the proximal half is retracted, or *vice versâ;* and if a drop of acid be placed on either half, the serial contraction of the feet in that half stops abruptly at the line of nerve-division. As a result of this complete physiological severance, when a detached ray so mutilated is inverted, it experiences much greater difficulty in righting itself than it does before the nerve was divided. The line of nerve-injury lies flat upon the floor of the tank, while the central and distal portions of the ray—i.e., the portions on either side of that line—assume various movements and shapes. The central portion is particularly apt to take on the form of an arch, in which the central end of the severed ray and the line of nerve-section constitute the points of support (tetanus?). Or the central end may from the first show paralysis, from which it never recovers. The distal end, on the other hand, usually continues active—twisting about in various directions, and eventually fastening its tip upon the floor of the tank to begin the spiral movement of righting itself. This movement then continues as far as the line of nerve-injury, where it invariably stops. The central portion may then be dragged over into the normal position, or may remain permanently inverted, according to the strength of pull exerted by the distal portion; as a rule it does not itself assist in the righting movement, although its feet usually continue protruded and mobile.

The above observations have reference to the common star-fish, but they apply equally to other star-fishes, except that in *Astropecten* single detached rays are not able to right themselves when inverted (owing to the feet not being used by

this species for this purpose, and to the other rays being absent), and that after division of the nerve in a ray of this species, the feet of the proximal portion usually manifest more activity than those of the distal. The destruction, however, of physiological continuity between the two portions is as complete as in the case of the common star-fish. Single detached rays of brittle-stars are able when inverted to right themselves; they wriggle round by means of their snake-like movements, and do not require, as in the case with the less active rays of *Astropecten*, the assistance of adjacent rays to effect the manœuvre. On the whole, then, it may be said, as a general statement, that in all the species of star-fish which we have observed, the effect of a transverse section of the nerve in a ray is that of completely destroying physiological continuity between the pedicels on either side of the section.

The only other experiments in nerve-section to which the simple anatomy of a star-fish exposes itself is that of dividing the nerve-ring in the disc; or, which is virtually the same thing, while leaving this intact, dividing all the nerves where they pass from it into the rays. In specimens mutilated by severing the nerves at the base of each of the five rays, or by dividing the nerve-ring between each ray, the animal loses all power of co-ordination among its rays. When a common star-fish is so mutilated it does not crawl in the same determinate manner as an unmutilated animal, but, if it moves at all, it moves slowly and in various directions. When inverted, the power of effecting the righting manœuvre is seen to be gravely impaired, although eventually it is always accomplished. There is a marked tendency, as compared with unmutilated specimens, to a promiscuous distribution of spirals and doublings, so that instead of a definite plan of the manœuvre being formed from the first, as is usually the case with unmutilated specimens, such a plan is never formed at all; among the five rays there is a continual change of uncoordinated movements, so that the righting seems to be eventually effected by a mere accidental prepotency of some of the righting movements over others.

When entire star-fish are mutilated by a section of each nerve trunk half-way up each ray, and the animal is then

placed upon its back, the tetanic contraction of the muscles in the rays before mentioned as occurring under this form of section in detached rays, has the effect, when now occurring in all the rays, of elevating the disc from the floor of the tank. This opisthotonous-like spasm is not, however, permanent; and the distal ends of the rays forming adhesions to the floor of the tank, the animal eventually rights itself, though much more slowly than unmutilated specimens. After it has righted itself, although it twists about the distal portions of the rays, it does not begin to crawl for a long time, and when it does so, it crawls in a slow and indeterminate manner. Star-fish so mutilated, however, can ascend perpendicular surfaces.

The loss of co-ordination between the rays caused by division of the nerve-ring in the disc is rendered most conspicuous in brittle-stars, from the circumstance that in locomotion and in righting so much here depends upon co-ordinated muscular contraction of the rays. Thus, for instance, when a brittle-star has its nerve-ring severed between each ray, an interesting series of events follows. First, there is a long period of profound shock—spontaneity, and even irritability, being almost suspended, and the rays appearing to be rigid, as if in tetanic spasm. After a time, feeble spontaneity returns—the animal, however, not moving in any determinate direction. Irritability also returns, but only for the rays immediately irritated, stimulation of one ray causing active writhing movements in that ray, but not affecting, or only feebly affecting, the other rays. The animal, therefore, is quite unable to escape from the source of irritation, the aimless movements of the rays now forming a very marked contrast to the instantaneous and vigorous leaping movements of escape which are manifested by unmutilated specimens. Moreover, unmutilated specimens will vigorously leap away, not only from stimulation of the rays, but also from that of the disc; but those with their nerve-ring cut make no attempts to escape, even from the most violent stimulation of the disc. In other words, the disc is entirely severed from all physiological connection with the rays.

If the nerve-ring be divided at two points, one on either side of a ray, that ray becomes physiologically separated from the rest of the organism. If the two nerve-divisions are so

placed as to include two adjacent rays—i.e., if one cut is on one side of a ray and the other on the further side of an adjacent ray—then these two rays remain in physiological continuity with one another, although they suffer physiological separation from the other three. When a brittle-star is completely divided into two portions, one portion having two arms and the other three, both portions begin actively to turn over on their backs, again upon their faces, again upon their backs, and so on alternately for an indefinite number of times. These movements arise from the rays, under the influence of stimulation caused by the section, seeking to perform their natural movements of leaping, which however end, on account of the weight of the other rays being absent, in turning themselves over. An entire brittle-star when placed on its back after division of its nerve-ring is not able to right itself, owing to the destruction of co-ordination among its rays. *Astropecten*, under similar circumstances, at first bends its rays about in various ways, with a preponderant disposition to assume the form of a tulip, and keeps its ambulacral feet in active movement. But after half an hour, or an hour, the feet generally become retracted and the rays nearly motionless—the animal, like a brittle-star, remaining permanently on its back. In this, as in other species, the effect of dividing the nerve-ring on either side of a ray is that of destroying its physiological connection with the rest of the animal, the feet in that ray, although still remaining feebly active, no longer taking part in any co-ordinated movement—that ray, therefore, being merely dragged along by the others.

Under this division it only remains further to be said, that section of the nerve-ring in the disc, or the nerve-trunks of the rays, although as we have seen so completely destroying physiological continuity in the rows of ambulacral feet and muscular system of the animal, does not destroy physiological continuity in the external nerve plexus; for, however much the nerve-ring and nerve-trunks may be injured, stimulation of the dorsal surface of the animal throws all the ambulacral feet and all the muscular system of the rays into active movement. This fact proves that the ambulacral feet and the muscles are all held in nervous connection with one another

by the external plexus, without reference to the integrity of the main nerve-trunks.

If a cork-borer be applied to the external surface of the shell of an *Echinus*, and rotated there till the calcareous substance of the shell is reached, and therefore a continuous circular section of the overlying tissues effected, it is invariably found that the spines and pedicellariæ within the circular area are physiologically separated from the contiguous spines and pedicellariæ, as regards local reflex excitability. That is to say, if any part of this circular area be stimulated, all the spines and pedicellariæ within that area immediately respond to the stimulation in the ordinary way; while none of the spines or pedicellariæ surrounding the area are affected. Similarly, if any part of the shell external to the circumscribed area be stimulated, the spines and pedicellariæ within the area are not affected. These facts prove that the function which is manifested by these appendages, of localising and gathering round a seat of stimulation, is exclusively dependent upon the external nerve plexus. It is needless to add that in this experiment it does not signify of what size or shape or by what means the physiological island is made, so long as the destruction of the nervous plexus by a closed curve of injury is rendered complete. In order to ascertain whether, in the case of an unclosed curve of injury, any irradiation of a stimulus would take place round the ends of the curve, we made sundry kinds of section. It is, however, needless to describe these, for they all showed that, after injury of a part of the plexus, there is no irradiation of the stimulus round the ends of the injury. Thus, for instance, if a short straight line of injury be made, by drawing the point of a scalpel over the shell, say along the equator of the animal, and if a stimulus be afterwards applied on either side of that line, even quite close to one of its ends, no effect will be exerted on the spines or pedicellariæ on the other side of the line. This complete inability of a stimulus to escape round the ends of an injury forms a marked contrast to the almost unlimited degree in which such escape takes place in the more primitive nervous plexus of the medusæ.[1]

[1] See 'Locomotor System of Medusæ,' Phil. Trans. 1875.

Although the nervous connections on which the spines and pedicellariæ depend for their function of localising and closing round a seat of stimulation are thus shown to be completely destroyed by injury of the external plexus, other nervous connections, upon which another function of the spines depends, are not in the smallest degree impaired by such injury. This other function is that which brings about the general co-ordinated action of all the spines for the purposes of locomotion. That this function is not impaired by injury of the external plexus is proved by the fact that, if the area within a closed line of injury on the surface of the shell be strongly irritated, all the spines over the whole surface begin to manifest their peculiar bristling movements, and by this co-ordinated action rapidly move the animal in a straight line of escape from the source of irritation; the injury to the external plexus, although completely separating the spines enclosed by it from their neighbouring spines as regards what may be called their local function of seizing the instrument of stimulation, nevertheless leaves them in undisturbed connection with all the other spines in the organism as regards what may be called their universal function of locomotion.

Evidently, therefore, this more universal function must depend upon some other set of nervous connections; and experiment shows that these are distributed over all the *internal* surface of the shell. Our mode of experimenting was to divide the animal into two hemispheres, remove all the internal organs of both hemispheres (these operations producing no impairment of any of the functions of the pedicels, spines, or pedicellariæ), and then paint with strong acid the inside of the shell—completely washing out the acid after about a quarter of a minute's exposure. The results of a number of experiments conducted on this method may be thus epitomised :—

The effect of painting the back or inside of the shell with strong acid (e.g. pure HCl) is that of at first strongly stimulating the spines into bristling movements, and soon afterwards reducing them to a state of quiescence, in which they lie more or less flat, and in a peculiarly confused manner, that closely

resembles the appearance of corn when "laid" by the wind. The spines have now entirely lost both their spontaneity and their power of responding to a stimulus applied on the external surface of the shell—i.e. their local reflex excitability, or power of closing in upon a source of irritation. These effects may be produced over the whole external surface of the shell, by painting the whole of the internal surface; but if any part of the internal surface be left unpainted, the corresponding part of the external surface remains uninjured. Conversely, if all the internal surface be left unpainted except in certain lines or patches, it will only be corresponding lines and patches on the external surface that suffer injury. It makes no difference whether these lines or patches be painted in the course of the ambulacral feet, or anywhere in the inter-ambulacral spaces.

The above remarks, which have reference to the spines, apply equally to the pedicellariæ, except that their spontaneity and reflex irritability are not destroyed, but only impaired.

Some hours after the operation it usually happens that the spontaneity and reflex irritability of the spines return, though in a feeble degree, and also those of the pedicellariæ, in a more marked degree. This applies especially to the reflex irritability of the pedicellariæ; for while their spontaneity does not return in full degree, their reflex irritability does—or almost in full degree.

These experiments, therefore, seem to point to the conclusions—1st, that the general co-ordination of the spines is dependent on the integrity of an internal nerve-plexus; 2nd, that the internal plexus is everywhere in intimate connection with the external; and 3rd, that complete destruction of the former, while profoundly influencing the functions of the latter, nevertheless does not wholly destroy them.[1]

In order that a more clear conception may be rendered of

[1] These three conclusions, first reached by the experiments described, were afterwards fully confirmed by histological investigation. The internal plexus is spread over the whole interior surface of the shell, and is everywhere in communication with the external plexus by means of delicate nerve-fibres which pass between the numerous plates of which the shell is composed.

the experiments on which these conclusions are based, we shall here quote from our notes one complete observation :—

"*Echinus* was divided into two hemispheres.

"After evisceration one hemisphere was painted over whole of internal surface with HNO_3. (A.)

"The other was painted down one row of ambulacral plates, and also down the inter-ambulacral plates at another part of internal shell. (B.)

"In (A) the spines were 'laid'; spontaneity and reflex irritability almost totally destroyed.

"In (B) similar effects observed above painted areas—unpainted areas unimpaired.

"Three hours after, no considerable recovery where painted; unpainted areas as active as before."

One further point, brought out by further experiments, may here be most conveniently mentioned; it is that a specially great influence, or shock, seems to be exerted on the external plexus by injury of the hypothetical internal plexus *along the lines of the ambulacral pores*. The following observations will serve to show this :—

"Another specimen was divided into two hemispheres. In one hemisphere two adjacent ambulacral rows were thoroughly scraped on internal surface of shell, and then well rubbed with sandpaper and brickdust.[1] The spines along these lines were laid in a very marked way, while spontaneity and reflex irritability, not only along them, *but also in the inter-ambulacral spaces between them*, were completely destroyed. The rest of the hemisphere was normally active.

"Ten minutes after operation the laid spines became more erect, and reflex irritability partly returned.

"Twenty minutes after operation pedicellariæ nearly completely recovered spontaneity and reflex irritability; spines still very imperfectly so.

"Two hours after operation both spines and pedicellariæ

[1] This method of destroying the internal plexus was here adopted in preference to the method of painting with acid, in order to avoid a possible source of fallacy in some of the acid passing through the perforations of the shell, and so finding its way over the external surface. All our experiments with acid were on other specimens controlled by similar experiments conducted on this method.

of the inter-ambulacral area *completely recovered in all respects.*"

If an *Echinus* is divided into two hemispheres by an incision carried from pole to pole through any meridian, the two hemispheres will live for days, crawling about in the same manner as entire animals; if their ocular plates are not injured, they seek the light, and when inverted they right themselves. The same observations apply to smaller segments, and even to single detached rows of ambulacral feet. The latter are, of course, analogous to the single detached rays of a star-fish, so far as the system of ambulacral feet is concerned; but looking to the more complicated apparatus of locomotion (spines and pedicellariæ), as well as to the rigid consistence and awkward shape of the segment—standing erect, instead of lying flat—the appearance presented by such a segment in locomotion is much more curious, if not surprising, than that presented by the analogous part of a star-fish under similar circumstances. It is still more surprising that such a fifth-part segment of an *Echinus* will, when propped up on its ab-oral pole, right itself after the manner of larger segments or entire animals. They, however, experience more difficulty in doing so, and very often, or indeed generally, fail to complete the manœuvre.

We are now face to face with the question—Is the action of the ambulacral feet in executing these righting movements of a merely serial kind, or does it depend upon nervous co-ordination? We have found this question very difficult of solution, and in the end have arrived at the conclusion that both principles are combined—the action of the feet being serial, but also assisted by nervous co-ordination. The experiments which lead us to this conclusion are as follows:—

If an unmutilated *Echinus* be suspended by a thread in an inverted position half-way up the side of a tank, in such a way that the ambulacral feet on one side of the ab-oral pole are alone able to reach the perpendicular wall, these feet as quickly as they can establish their attachments to that wall; the thread being then removed, the *Echinus* is left sticking to the side of the tank in an inverted position by means of the ab-oral ends of two adjacent feet-rows. Under these circumstances, as we should expect from the previous experiments,

the animal sets about righting itself as quickly as possible. Now, if the righting action of the feet were entirely and only of a serial character, the righting would require to be performed by rearing the animal upwards; the effect of foot after foot in the same rows being applied in succession to the side of the tank, would require to be that of rotating the globular shell against the side of the tank towards the surface of the water, and therefore against the action of gravity. This is sometimes done, which proves that the energy required to perform the feat is not more than a healthy *Echinus* can expend. But much more frequently the *Echinus* adopts another device, and the only one by which it is possible for him to attain his purpose without the labour of rotating upwards; he rotates laterally and downwards in the form of a spiral. Thus, let us call the five feet-rows, 1, 2, 3, 4, and 5, and suppose that rows 1 and 2 are in use near their ab-oral ends in holding the animal inverted against the perpendicular side of a tank. The downward spiral rotation would then be effected by gradually releasing the outer feet in row 1, and simultaneously attaching the outer feet in row 2 (i.e. those nearest to row 3, and furthest from row 1), as far as possible to the outer side of that row. The effect of this is to make the globe roll far enough to that side to enable the inner feet of row 3 (i.e. the[illegible]arest to row 2), when fully protruded, to touch the side of the tank. They establish their adhesions, and the residue of feet in row 1, now leaving go their hold; these new adhesions serve to roll the globe still further round in the same direction of lateral rotation, and so the process continues from row to row; but the globe does not merely roll along in a horizontal direction, or at the same level in the water, for each new row that comes into action takes care, so to speak, that the feet which it employs shall be those which are as far below the level of the feet in the row last employed as their length when fully protruded (i.e. their power of touching the tank) renders possible. The rotation of the globe thus becomes a double one, lateral and downwards, till the animal assumes its normal position with its oral pole against the perpendicular tank wall. So considerable is the rotation in the downward direction, that the normal position is

generally attained before one complete lateral, or equatorial, rotation is completed.

The result of this experiment, therefore, implies that the righting movements are due to something more than the merely successive action of the series of feet to which the work of righting the animal may happen to be given. The same conclusion is pointed to by the results of the following experiment.

A number of vigorous *Echini* were thoroughly shaved with a scalpel over the whole half of one hemisphere—i.e. the half from the equator to the oral pole. They were then inverted on their ab-oral poles. The object of the experiment was to see what the *Echini* which were thus deprived of the lower half of three feet-rows would do when, in executing their righting manœuvres, they attained to the equatorial position and then found no feet wherewith to continue the manœuvre. The result of this experiment was first of all to show us that the *Echini* invariably chose the unmutilated feet-rows wherewith to right themselves. Probably this is to be explained, either by the general principle to which the escape from injury is due—viz. that injury inflicted on one side of an echinoderm stimulates into increased activity the locomotor organs of the opposite side,—or by the consideration that destruction of the lower half of a row very probably induces some degree of shock in the remaining half, and so leaves the corresponding parts of the unmutilated rows prepotent over the mutilated one. Be this as it may, however, we found that the difficulty was easily overcome by tilting the animal over upon its mutilated feet-rows sufficiently far to prevent the unmutilated rows from reaching the floor of the tank. When held steadily in this position for a short time, the mutilated rows established their adhesions, and the *Echinus* was then left to itself. Under these circumstances an *Echinus* will always continue the manœuvre along the mutilated feet-rows with which it was begun, till the globe reaches the position of resting upon its equator, and therefore arrives at the line where the shaved area commences. The animal then remains for hours in this position, with a gradual but continuous motion backwards, which appears to be due to the successive slipping of the spines—these organs in the righting movements being always used as props for the

ambulacral feet to pull against while rearing the globe to its equatorial position, and in performing this function on a slate floor the spines are liable often to slip. The only other motion exhibited by *Echini* thus situated is that of a slow rolling movement, now to one side and now to another, according to the prepotency of the pull exerted by this or that row of ambulacral feet. Things continue in this way until the slow backward movement happens to bring the animal against some side of the tank, when the uninjured rows of ambulacral feet immediately adhere to the surface and rotate the animal upwards or horizontally, until it attains the normal position. But if care be taken to prevent contact with any side of the tank, the mutilated *Echinus* will remain propped on its equator for days; it never adopts the simple expedient of reversing the action of its mutilated feet-rows, so as to bring the globe again upon its ab-oral pole and get its unmutilated feet-rows into action. At first sight, therefore, this result seems to point to the conclusion that the righting movements are of a merely serial kind; it seems to indicate that the feet are only able to act in one direction, from ab-oral to oral pole, and that there is not sufficient central co-ordination to induce them to act in the opposite direction, when it is found to be useless, from the interruption of the series, to continue the manœuvre in the ordinary direction. But a little closer thought will show that this conclusion is not justified by the facts. For even if we assume that the righting movements of the feet are entirely due to some central co-ordinating influence, it does not follow, when the execution of these movements is interrupted by the highly artificial means of shaving off one-half the feet-rows, that the central co-ordinating apparatus should be adapted to meet so unnatural a state of things. Suppose, for instance, that it is an incipient sense of gravity that determines this central apparatus to work the feet-rows serially, in order to rotate the animal into its normal position; it does not follow that, under any circumstances, the stimulus supplied by this sense of gravity should induce the central apparatus to *reverse* the action of the feet-rows; for to do this would, under any circumstances, be to act in opposition to the stimulus supposed. Only if we were to imagine that

the central apparatus, if present, must possess a true psychological element capable of sufficient intelligence to reflect that by temporarily acting in opposition to the sense of gravity the peculiar exigencies of the situation might be overcome—only then could we fairly argue that the result of these experiments shows the righting movements of the feet to be purely serial, or wholly independent of nervous co-ordination. As a matter of physiology, therefore, the only question in the present connection which we have to consider is this—is the mechanism of the ambulacral feet so constructed as to insure that their serial action shall always take place in the same direction? For if it can be shown that their serial action may take place indifferently in either direction, it would follow that the persistency with which the shaved *Echini* continued reared upon their equators is the expression of some stimulus (such as a sense of gravity) continuously acting upon some central apparatus, and so impelling the latter to a continuous, though fruitless, endeavour at co-ordinating the absent feet. If the righting movements were wholly independent of any such central apparatus, and due only to the serial action of the feet, we should expect that (supposing the feet to be able to act serially in either direction) when the equator position had been attained in shaved specimens, it would not be maintained. For if there were no constant stimulus emanating from any co-ordinating centre persistently trying to induce the absent feet to continue the serial action in the same direction, we should expect, if serial action can take place in either direction, that after a time it should begin to take place in the opposite direction; upon the supposition that the feet may act serially in either direction, there is no more reason why a shaved *Echinus* should remain permanently reared upon its equator. than there is that it should remain permanently inverted upon its pole, and therefore the fact that in the latter position the feet set about an immediate rotation of the animal, while in the former and quite as unnatural position they hold the animal in persistent stasis—this fact tends to show that the righting movements of the feet are something more than serial. The question, therefore, that we set ourselves to determine was, whether the serial action of the feet invariably takes

place in the direction of ab-oral to oral pole, or may likewise take place in the opposite direction. We found that it may take place in the opposite direction, as the following observations prove. We have seen a shaved specimen, which after remaining for several hours on its equator was accidentally rolled over into its normal position, forthwith begin to rear itself upon its uninjured feet-rows. Executing this what we may call an inverted righting movement with activity, the *Echinus* was speedily reared into the equatorial position on the opposite side to that from which it had just fallen—and in order to do this, it is needless to say, the feet of the uninjured rows had to be used serially in the direction opposite to that in which they are required to act when executing the ordinary righting manœuvre. We may wonder what the stimulus can have been which induced this *Echinus* spontaneously to rise upon its equator; but it is of interest in this connection to add that, so soon as the equator position had been attained, and so soon therefore as any further action of the uninjured feet-rows in the same direction would have begun to get the animal into a position of ever-increasing difficulty as regards subsequent righting, so soon did the serial action in this direction cease, became reversed, and so again brought the animal gently into its normal position.

We have also seen wholly uninjured specimens when reaching the surface of the water by crawling up the sides of a tank, spontaneously rear themselves upon their equators and remain in that position for several minutes; but we have never observed a case of such rotation carried further than the equatorial line. The fact, however, that such rotation from oral to ab-oral pole can take place over half the whole length of a pair of feet-rows, proves that the feet may act serially in either direction. The same thing is further proved by the fact that single detached rays of star-fish sometimes crawl backwards, and that in entire star-fish the rays opposite to the direction of advance work their ambulacral feet centripetally, while those on the rays facing that direction work centrifugally.

Lastly, as proof that the ambulacral feet of *Echinus* are under the control of some centralising apparatus when execut-

ing the righting manœuvre, we may state one other fact. When the righting manœuvre is nearly completed by the rows engaged in executing it, the lower feet in the other rows become strongly protruded and curved downwards, in anticipation of shortly coming into contact with the floor of the tank when the righting manœuvre shall have been completed. This fact tends to show that all the ambulacral feet of the animal are, like all the spines, held in mutual communication with one another by some centralising mechanism.

Such, then, is the evidence we have to adduce for the purpose of showing that the action of the ambulacral feet is not entirely or only of a serial kind, but is, in part at all events, dependent upon some centralising influence by which all the feet, like all the spines, are rendered capable of truly co-ordinated action. We have next to adduce our evidence to show that the action of the ambulacral feet, although as we have seen in some measure, is not exclusively dependent on this centralising influence.

In order to show this we must first narrate the experiments whereby we succeeded in ascertaining the central apparatus, on the integrity of which both the feet and the spines depend for their co-ordination. Having obtained the definite evidence of co-ordination which has now been fully detailed, we of course sought to localise the centre to which this co-ordination is due; and in searching for this centre our thoughts naturally turned to the only part of the nervous system where we could reasonably expect to find it. This part is the central nerve-ring, and, as we had anticipated, experiment revealed unmistakable evidence of this being the centre of which we were in search.

If a circular incision be made all the way round the lantern of an *Echinus*, at a sufficient distance from the lantern to insure that the connections of the nerve-ring with the rest of the organism shall be severed, the following results are produced:—

1. *Pedicels.*—Spontaneity impaired, though not destroyed. They are protruded, but not in such numbers or with so much activity as in the unmutilated animal; they, however, form their adhesions in the ordinary manner whenever they come

into contact with a sold surface, and therefore their function of anchoring the *Echinus* securely remains unimpaired. They also still continue able to crawl, but they do so feebly and no longer in a determinate direction; the animal therefore advances slowly and in a very uncertain manner, frequently changing its direction of advance, and manifesting a marked tendency to rotate upon its own axis, either without moving from one spot or gyrating round and round some one or more centres in a wholly aimless way. The animals, however are still able to climb perpendicular surfaces, though in a most uncertain manner. When stimulated strongly the activity of the animal is increased, but its power of escaping from the source of injury is completely destroyed; it crawls indifferently in any direction—as likely as not *towards* the source of injury—rotates upon its axis, and after crawling some distance in one direction may very likely reverse that direction, and so return to the place from which it started. All these movements, standing in such marked contrast to those exhibited by unmutilated specimens under similar circumstances, prove that the co-ordination of the ambulacral feet has been destroyed. On the other hand, the fact that they continue able to act *at all* proves that their activity is not *wholly* dependent upon the nerve-centre; all that the destruction of this centre entails is the destruction of their power of *co-ordinated* action.

When perfectly fresh and vigorous specimens are inverted, a proportion of about three to four remain permanently inverted till they die. As this is never the case with perfectly fresh and vigorous specimens when unmutilated, there can be no question that destruction of the nerve-centre exerts a profound influence on the action of the ambulacral feet upon which the execution of the righting manœuvre depends. On the other hand, the fact that a certain proportion of individuals continue able to execute this manœuvre after destruction of the nerve-centre—although they never do so without much difficulty and after a long time—proves that the integrity of this centre is not absolutely essential to the execution of this manœuvre. Therefore, as experiment has failed to reveal to us any other general nerve-centre in the animal, and as even a

segment of the animal containing but a single row of feet is in many cases able to perform this manœuvre, we conclude, as previously stated, that the action of the feet in performing these righting movements is partly of a serial character, although, for reasons mentioned in the two previous paragraphs we further conclude that in the unmutilated animal these movements are largely assisted by the co-ordinating influence that emanates from the nervous centre.

2. *Pedicellariæ.*—No effect whatever is produced upon these organs by destruction of the nerve-ring.

3. *Spines.*—These organs, on the other hand, are profoundly affected—not, indeed, as regards their spontaneity and the function which they share with the pedicellariæ of closing round any instrument of stimulation, but as regards their other two more general functions. That the particular or local function which they share with the pedicellariæ should not be impaired by destruction of the general nerve-centre is no more than we might expect from those experiments detailed in previous parts of this paper, which proved that this function is performed exclusively by the numberless local nerve-centres (cells) of the external plexus. Thus, for instance, it will be remembered that when a small piece is cut out of the shell of an *Echinus* or *Spatangus*, and the internal surface of that piece painted with acid, its spines and pedicellariæ, although severed from any possible nervous connection save those of the external plexus, will continue to perform their function of localising a seat of stimulation.

As regards, then, the more general function of the spines, we have first to consider what we may term their general reflex irritability—i.e. their power of active bristling response all over the animal when any part of its surface is strongly stimulated, as by burning. Immediately after the operation of removing the nerve-centre this function is found to be in abeyance, or nearly so—strong stimulation of one part of the animal not being followed by any response of the spines in other parts. This effect, however, completely passes off within several hours after the operation, and is therefore to be attributed to shock. The fact, however, that the influence of shock is thus revealed in temporarily suspending this general nervous

communication among the spines, proves that this general communication, unlike the more special one which they share with the pedicellariæ, is itself in communication with the central nervous ring. Further, the experiments detailed in a previous part of this paper prove that the medium of communication is in this case the *internal* nervous plexus, as in the case just mentioned the medium of communication has been proved to be the *external* nervous plexus. And as the effect of the operation in question is only transitory—after recovery from shock the spines being as responsive as ever to severe stimulation—we must conclude that the general communication between the spines is maintained by the direct conductility of the internal plexus, and is not of the nature of a reflex in which the nerve-ring is concerned as a general centre. The only effect of removing this nerve-ring is temporarily to paralyse, through shock, the internal plexus with which the ring is connected.

Lastly, the effect of removing the nerve-ring is that of completely and permanently destroying the general co-ordination of the spines; that is to say, after this operation these organs are never again of any use to the *Echinus* for the purpose of locomotion. When the animal is placed upon a table and a lighted spirit lamp held against one side, although all the spines will manifest their active bristling movements, they will not co-operate to move the animal away from the source of irritation, as is so invariably the case with unmutilated specimens. Removal of the nerve-ring has entirely destroyed the general co-ordination of the spines.

ON OPHTHALMOPLEGIA EXTERNA, IN CONJUNCTION WITH TABES DORSALIS, WITH SOME REMARKS ON GASTRIC CRISES.

BY THOMAS BUZZARD, M.D., F.R.C.P.

Physician to the National Hospital for the Paralysed and Epileptic.

In the course of the last three years I have had two cases of ophthalmoplegia with tabes under my care in the hospital. One of them, a female, is, I believe, still living, but I have not seen her for some time past. The other, a male, died in the hospital, and an autopsy was obtained. Portions of the hardened nerve-centres were forwarded to Dr. Bevan Lewis, of the West Riding Asylum, Wakefield, who has been kind enough to examine them microscopically, and furnish me with the valuable report and drawing which are appended to the case.

A. B., a female, æt. 25, was admitted into the National Hospital for the Paralysed and Epileptic on January 16th, 1879. The following account of her case is partly derived from notes which were made by Mr. A. E. Broster, then Resident Medical officer.

On the right side there is semi-ptosis of the eyelid, together with paralysis of the recti and obliqui muscles, which appears to be absolute, with the exception that the inferior rectus can slightly move the eyeball.

On the left side there is ptosis of the eyelid with paralysis of all the recti and obliqui, with the exception of the external rectus.

The right pupil is 4 mm., the left 4·5 mm. in diameter. There is no action to light in either, but they act a little during attempted accommodation. (I may say, in general terms, that no muscle of either eye acted properly except the

left external rectus.) There is no affection of cutaneous sensibility or motor power in the range of the fifth nerve.

Taste and hearing are good; the tongue is protruded straight, but with some quivering. The right side of the face does not move so perfectly as the left.

The arms are somewhat weak. The grasp of the right hand measures 52, the left 55. There is slight anæsthesia to touch and pain in the first two fingers of the right hand. When asked to touch the tip of the nose with the right index finger she missed it altogether, but reached it, though with some difficulty, with her left.

As she sits she can raise both knees, but on trying to stand her legs give way, and she needs the help of two persons to walk. Her gait is characteristically ataxic.

She cannot stand by herself with her eyes open; if they are shut the difficulty is greatly increased.

She feels the ground imperfectly with the soles of the feet, and in these she gets acute "pins and needles," which cause her legs to "jump." The muscular sense of the lower extremities is diminished. The knee phenomenon is absent in each leg. There is no foot-clonus.

Besides a general emaciation of the arms and legs, certain muscular groups are picked out by atrophy, especially the right serratus magnus and right interscapular muscles—so that the right scapula tends to drop by its weight—the right pectoralis major, and both sternomastoids.

The trapezii and the muscles of the back generally are thin. There is atrophy of the glutæi, especially on the left side.

The patient suffers occasionally from very severe spasms and pain in the epigastric region together with vomiting (gastric crises).

She complains that she is scarcely ever free from pain. There is a burning pain at the back of the neck and behind the ears, a heavy aching feeling across the forehead, and, in addition, she has very sharp and sudden pains coming and going in the skin at the top of the head.

Her arms feel as if they were being gnawed, and there have been sharp shooting pains in the course of the median nerves, leaving an after-feeling of soreness.

She has shooting pains in the lower part of the abdomen, and what she describes as a "dull" pain in the vagina. There is a feeling of fulness in the abdomen and of oppression over the lower half of the chest, which is so severe at times that it is as though suffocation were imminent.

She has a constant sense of starvation in spite of eating largely. Her own words are, "I always feel hungry—always feel starved. When at home I never seemed satisfied, and ate all sorts of things; in fact everything I could get hold of."

The tongue "feels hard," her throat is dry, and she has a sensation of choking. She can swallow without difficulty. There have been at times severe cramps in the left flank.

She has numb feelings and creeping sensations down the legs and thighs, with aching of the knees. If her legs are allowed to dangle, they feel as though they were being screwed off at the knees.

Seated in a chair she feels giddy and appears to lose all power in the back. A month ago she suffered from what is described as a "starting" pain (so sharp that she was compelled to cry out) in the front of both thighs, and at times a similar pain has come across the dorsum of either foot, causing the feet to start.

At 17 this girl contracted a chancre, which was followed by sore throat and copper-coloured rashes.

At 22, according to her account, she had a bad cold, after which she was always weary and could not rid herself of a tightness in the chest.

She had severe aching pain in the back and vagina, with frequent desire and imperfect ability to micturate. About the same time there was internal strabismus of a passing character.

Next she complained of burning sensations in her loins and her belly seemed large.

A few months later and her right eyelid began to droop, and she had giddiness and pains in the legs, "sharp like needles," causing her legs to jump. The right eyelid recovered its power, and then the left lid drooped. She went into a hospital and her legs began to fail her. She staggered as if drunk, the right shoulder wasted, and the right eyeball

became fixed, as it is now, and the left eyeball began to follow its example.

Next the right lid began to droop again and she gradually wasted. The pains have become more frequent and severe.

She was admitted into our hospital in January and discharged in May.

The treatment consisted in mercurial inunction carried to mild salivation together with iodide of potassium, in doses of 20 grains, three times daily.

Her pains were a good deal relieved by extract of Indian hemp, but beyond this she could not be said to have derived any particular benefit from the treatment, and she quitted the hospital in much the same state as that which she presented on admission.

Before making any comments upon this case it will be convenient if I describe the other one.

X. Y., æt. 36, served for 16 years in the army (10 years in India), and was invalided on account of heart disease.

He was married and had six children. In his family history there was nothing of note except that he had a sister who was paralysed.

For himself he had rheumatic fever ten years before his admission here, and had once suffered from gonorrhœa, but never to his knowledge from syphilis.

He was admitted into the hospital in 1880.

By his own account his illness had only begun in the preceding February, but it appeared on inquiry that for five years he had been subject to dragging "rheumatic" pains which were not sharp or sudden.

Not till six months before he applied here did he begin to have sharp, darting pains in the legs, and also in the fingers. They were very sudden, and described as being like "sparks of electricity" recurring through his limbs. About March he began to stagger in walking.

About two years previously he had begun to see double and had "twitching under the eyes." His sight had got bad since Christmas, but he was not aware that his eyes were fixed till his attention was called to it here. He had rapidly become

very deaf, and for three months there had been difficulty in swallowing. He had nearly choked on several occasions. He had never suffered from attacks of vomiting.

His state, as taken by Dr. Beevor in September, was as follows:—

Patient appears considerably older than his years. He has a dull, heavy, listless look which seems to be due to his eyeballs being motionless. The eyelids droop, the right more than the left. He can close them with equal ease apparently on either side, but in opening them as wide as he can he is unable to raise the eyelids to a normal extent, and the right still less than the left.

The eyeballs are rather prominent. They are completely fixed, the gaze being always directed straight forward, with a slight divergence of the optical axis. The right pupil measures 3·5 mm., the left 3 mm.

They are both insensitive to light, and they do not contract when he tries to look at a near object; but it is to be observed that he is unable to converge the eyes, owing to the paralysis of the external muscles of the eyeballs.

The masseter muscles contract firmly and equally. He cannot whistle, and says his food collects between his cheeks and teeth, especially on the left side. The tongue is protruded almost straight, slightly inclined to the left side.

He can swallow liquids pretty well, but takes a long time to swallow solids, especially if they are dry, like bread. Smell and taste are not apparently affected. Hearing on both sides is so bad that he needs to be shouted at; the degree of deafness varies. There is subjective sensation of booming of bells, especially in the right ear.

By the ophthalmoscope no change is to be noted in the optic discs. Can just read $8\frac{1}{2}$ Snellen with either eye. Colour vision good. Distant objects sometimes appear double; near ones, never.

The skin of the forehead seems rather less sensitive to touch on the left than the right side, but there is no marked impairment of sensibility in the region of the fifth nerve. In the rest of the body it is perfect. The upper limbs are somewhat wasted about the shoulders and forearms, but not to any marked

extent. The movements of the arms are free, and the grasp 35 with the right, 30 with the left, hand.

The lower limbs are rather more wasted, and the calf muscles are especially flaccid. He has free movements with his legs, and considerable power in them when lying down. The wasting of limbs is of the nature of general emaciation, not of progressive muscular atrophy.

When his eyes are closed he staggers, and would fall. In walking he is very shaky, and especially when he turns. He does not bring his feet down with a stamp.

The patellar tendon reflex is absent on each side. There is no ankle-clonus. Sole reflex is present, but small on each side.

Cremasteric reflex absent; abdominal only imperfectly obtained; the epigastric is marked. The faradic excitability of the muscles of the thighs and legs is very slightly indeed below the normal.

There is no delay in the transmission of impressions of touch or pain, and he can localise correctly the slightest touch on the arms and legs.

The lungs are free from dulness. A few râles are heard in the interscapular region. At base of the heart a loud double see-saw murmur, the pulse 68, of water-hammer character. The brachial arteries at the elbow are tortuous, and roll under the finger. The urine contains no albumen nor sugar.

When this man had been about three weeks in the hospital he was taken one day (September 28th) with a fit of coughing, which was followed by vomiting.

He was then seized with intense dyspnœa. The face and lips suddenly became of a livid blue colour; the mouth, opened wide, gave exit to a moaning cry of very distressing character. He was immediately got into bed and propped up, whilst brandy was administered by enema.

After about twenty minutes he was able to speak, having gradually recovered from the dyspnœa. His mind appeared confused for a little time afterwards.

Next day his temperature was 100·6. There was no dulness in the chest, but râles were heard at the bases of lungs.

On Sept. 30th he began to have such difficulty in swallowing

that food was henceforth administered by enema. He gradually got lower. On Oct. 2nd the catheter required to be used. The pulse numbered 100, regular, but very compressible.

Respirations 28 in the minute. There were râles in the chest. On Oct. 3rd his temperature, which in the morning was 102·6, marked 104 in the afternoon, and in the evening 101·2. He became excited and delirious. Urine contained a little albumen. Next morning he appeared almost moribund; but answered questions, and was able to swallow egg and milk with brandy.

His morning temperature was 102·2, pulse 104. Respirations 40, very shallow.

There was no dulness to be noted in the chest, but râles continued at the bases of the lungs. During Oct. 5th he continued to sink, attacks of dyspnœa occurring two or three times in the day, and on Oct. 6th he died.

An autopsy was made nineteen hours after death. There was nothing noticeable about the dura mater or the general aspect of the brain. On removing the cerebrum some of the cranial nerves could not be found. The right third nerve was seen *in situ*, but the left escaped observation.

On dissecting the outer wall of the cavernous sinus, the third and fourth pairs could be made out, but not the sixth. The fifth, seventh, eighth and ninth nerves were seen.

The nerves which could not be discovered had, no doubt, dwindled so much in size as to escape recognition. Section of the spinal cord disclosed no change to the naked eye.

The right side of the heart was full of dark clotted blood. The left side contained some ante-mortem clots. The mitral valves appeared slightly thickened. The aortic valves were healthy in appearance, but the sinuses of Valsalva were much dilated, and the whole of the ascending aorta was dilated.

The spinal cord with the medulla oblongata and portions of the mesocephale were hardened and submitted to microscopical examination by Dr. Bevan Lewis.

The following is the account which he has been kind enough to give me of the results of his examination.

HISTOLOGICAL NOTES ON A CASE OF TABES WITH OPHTHALMOPLEGIA EXTERNA. By Dr. Bevan Lewis.

The Spinal Cord.

Sections taken indiscriminately from any region of the cord exhibit very advanced degenerative changes invariably limited to the posterior column. The lesion, which is of the nature of grey degeneration, is fairly symmetrical in its hemispheric distribution throughout the different regions of the cord; but there is evidence in the distorted marginal contour of these columns in the lumbar cord (due to sclerous shrinking and contraction) that the lower realms have been earlier implicated, as they exhibit a later stage of sclerosis that what obtains in the higher divisions of the cord. To the naked eye all transverse sections when stained display the posterior columns mapped out with extreme distinctness by the far greater depth of tint which they attain in contrast with that of the antero-lateral columns. Aniline staining in this respect may be most favourably compared with the carmine sections, and exhibit with even greater distinctness this morbid coloration due to the preponderance of the connective elements. Similar features are observed under the low powers of the microscope, and the nature of the change indicated by the great increase of intermedullary connective which, invading irregularly the different portions of the tissue, separate whole fascicles of unaffected medullated tubes from one another by the intervening deep-stained sclerous tissue. The latter consists not alone of intermedullary fibrillated connective, but of numerous multi-caudate cells, which differ only in number, size, and readiness of staining from the normal cells of the medullary septa supporting the vascular network of the cord. These morbid elements usually measured ·027 mm. × ·013 mm., were extremely irregular in size and contour, threw out numerous delicate fibrous prolongations, and were generally associated with large, dilated, and tortuous blood vessels, the walls of which were covered by proliferating nuclei. Throughout the whole commissural and radicular zones of the posterior columns, these

vessels appeared both more numerous and more dilated than was the case in the normal cord used for comparison with the morbid specimens.

The spider-like connective cells were far more numerous in the post-commissural than in the posterior radicular zones, and were very scanty or wholly absent in the columns of Goll, where the fine fibrillated intervening connective predominated as the morbid element. In all the minute medullated tubes, the wasting of the medullary sheath was revealed at a glance by the great disproportionate size of the axis-cylinder, whilst in those of wider calibre measurements gave for large numbers an axis-cylinder of ·006 mm., or ·009 mm. for medullated tubes of ·011 mm.—a very appreciable degree of wasting. In the more advanced foci of sclerous change the medullary sheath was entirely absent, and remains of axis-cylinders dotted the embracing zones of connective. The regional distribution of the lesion exhibited the following characters from above downwards.

a. Cervical enlargement.—The most extreme sclerous change was observed in the medullated zone bordering upon the posterior commissure (post-commissural zone), which appeared to have been a focus of the most intense degenerative alteration. To the finely punctuated appearance given by the normal axis-cylinders is here superadded a mosaic of deeper and fainter stained areas corresponding to sites more or less sclerosed, and with this is conjoined a coarse dotting of the field due to the great increase in numbers of deeply-stained connective cells, and the divided orifices of numerous coarse blood-vessels. Immediately behind the commissure the medullated fibres are almost universally reduced in diameter, and although a few tubuli are seen, which attain the average large diameter of this zone (·014 mm.), and a few exceptional ones even rival those of the columns of Turck (·027 mm.), still the vast proportion are extremely reduced, whilst extensive sclerosed tracts embrace the remains of axis-cylinders or the minutest medullated tubes. It was in this region, as before stated, that the connective cell and distended vessel predominated. Next to this post-commissural zone, the radicular zones are the parts most gravely implicated—the anterior series of radicular fibres

suffering more severely than those behind them, the integrity of which may be clearly traced throughout an extensive course. A somewhat large islet of nearly healthy tissue bordered the more anterior segment of these radicular zones (cols. of Burdach), but the posterior segments of the same were sclerosed throughout. The median columns (cols. of Goll) were degenerated to an *equal degree* throughout the whole or greater part of their extent.

β. Dorsal region.—Here, as in the upper realms, the most intense change was concentrated upon the large medullated elements bordering upon the posterior commissure, whence the sclerous tissue fringed the columns of Burdach on either side, implicating to a very serious extent the posterior radicular fibres. Far more universally involved and degenerated than in the cervical cord, these radicular fibres were often completely destroyed, the islets of healthy tissue being very few, and surrounded on all sides by large quantities of inter-medullary connective, branched cells, and dilated, tortuous vessels. The sclerous change has also invaded in this region of the cord the posterior cornua as far as the emergence of the posterior roots, the change being somewhat more marked on one side than the other, a statement which also applies to the posterior radicular fibres. A very limited patch of degeneration is found in the median district, which, on either side of the so-called posterior fissure, is otherwise wholly unaffected by the lesion.

γ. Lumbar enlargement.—Bordering the posterior fissure on either side are two riband-like bands of deeply-stained sclerosed tissue. By subsequent contraction of this tissue the two lateral halves of the posterior columns have been almost completely rent asunder, being connected only by a slight bridge of degenerated tissue near the posterior margin of the cord. These retracted sides enclose an elliptic space betwixt them of some size, so that the area of the posterior columns is greatly reduced in extent. A similar dense sclerous tissue follows out the posterior border of the cord, extending to within a very short distance of the posterior roots. Apart, however, from this morbid fringe along the raphe and borders of the posterior columns, we also find advanced degenerative changes in the post-commissural zone, similar in site and in character to what

was described in higher regions, stopping short at the radicular zones, the fibres of which are less implicated than in any other region of the cord. In the lowest part of the lumbar enlargement, on the right side, a peculiar cyst-like cavity, 1·5 mm. deep by ·75 mm. wide, exists in the posterior cornu. It has condensed sclerosed margins, and occupies the site of a large proportion of the vertical fibres of this cornu, which ascend in front of the substantia gelatinosa. The fibres (horizontal) of the latter arch round it on either side, but not completely surrounding it, and appear compressed together by the former contents of the cavity which have now escaped. A few of the vertical fasciculi still remain intact.

Antero-lateral columns.—A careful examination of these columns in the cervical, dorsal, and lumbar regions was made, and the results enable me to state positively that the (*a*) direct cerebellar tracts, (*b*) the direct and crossed pyramidal tracts, and (*c*) Gowers' tracts were free from any appreciable lesion, the histological elements being well displayed and perfectly normal.

Anterior cornua.—A similar statement may be made for the anterior horns of grey matter. The neuroglia had a perfectly normal aspect; the small ascending fasciculi of minute medullated fibres were well developed; the nerve-cells were plump, slightly pigmented, and exhibited neither quantitative nor qualitative change. Their marginal fibres for the motor roots were beautifully shown in all sections and free from any morbid change, nor in any region was the slightest tendency exhibited to extension of the lesion from the posterior cornua.

To summarise the changes observed:—

a. Most advanced sclerous change in the post-commissural zones throughout all the regions of the spinal cord alike.

b. Extension along the posterior radicular zones of a minor degree of intensity, and implicating the radicular fibres causing their destruction to a slight extent in the cervical, to a still less extent in the lumbar, but to a very grave extent in the dorsal region.

c. The columns of Goll through the cervical region were almost completely sclerosed, but the degree of degenerative change was less than in the above-mentioned regions.

d. Median segment of dorsal posterior columns scarcely affected.

e. Median raphe and posterior border of the same columns in the lumbar cord sclerosed and distorted.

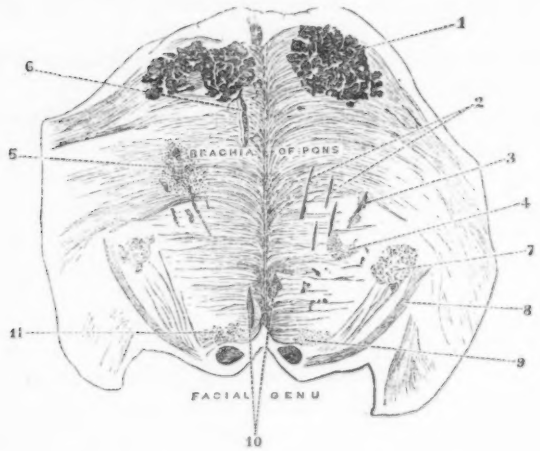
f. Small cyst-like cavity in gelatinous substance of posterior cornua in the lumbar region on the right side.

g. Implication of the posterior cornua by the same grey degeneration, but to a slight degree in both cervical and dorsal regions, extending usually to point of emergence of posterior roots.

h. In the sites of most advanced sclerosis (post-commissural and post-radicular zones) the size and number of the dilated blood-vessels formed a notable feature under a low objective.

i. Numerous amyloid bodies appear scattered throughout the posterior columns of most of the regions of the cord.

The pons and medulla.—Sections were carried through the nuclei of origin of the various bulbar nerves. Of those found along the lower half of the floor of the fourth ventricle—the accessory, hypoglossal, vagus and glosso-pharyngeal—the nuclei as well as the emergent or radicular fibres were found well displayed and perfectly intact. No diseased tract of tissue was anywhere apparent in the transverse sectional areas of this district, and the restiform columns and olivary nuclei and fibres were throughout free from lesion. Upon reaching the higher level of the origin of the sixth nerve, undoubted evidence was obtained of a morbid condition of this tract. The lesion was obviously a vascular one, and had secondarily implicated the emergent fibres from the abducens-facialis nucleus—the root fibres of the sixth pair. The nucleus, where it lies in front of the genu of the facial nerve, was represented by mere remnants of degenerated cells, and a punctated aspect of tissue from the resulting débris. The fibres of origin of the abducens, usually so clearly defined within the field embraced by the band of facial roots, were represented merely by an occasional narrow streak of minute and degenerated fasciculi taking their usual curved course, but lost to view after a short distance. Along the direction pursued by these diseased fasciculi were several large swollen and tortuous blood-vessels perfectly occluded by dark clots, their coats extensively diseased and frequently crowded by heaps of red blood cor-



1. Vertical fasciculi from crura.
2. Remains of roots of sixth nerve.
3. Diseased and plugged vessels covered with blood corpuscles.
4. Miliary extravasation.
5. Large focus of extravasation. [plugged.
6. Blood-vessel in advanced state of disease,
7. Posterior nucleus and ascending roots of the facial.
8. Facial nerves.
9, 11. Abducens facialis degenerated on both sides.
10. Diseased and plugged vessel.

puscles. Along the course of the same fibres of the sixth pair are several miliary apoplexies, which have probably induced the degenerative changes here observed. Apart however from these foci of extravasation, we find also innumerable red corpuscles crowding certain parts of the field on either side of the median raphe ; in fact the region of the abducens has been the seat of miliary apoplexies extensively induced by plugging of the nutrient vessels of this realm. In the rough sketch appended, I have endeavoured to localise a few of these diseased vessels and extravasations in a section taken at this level.

Level of Lemniscus.—Those vertical medullated fasciculi which limit the tegmentum in front, and are embraced by the most posterior fibres of the brachia of the pons, exhibit a notable increase of their connective elements. These fibres, associated with those from the fillet of the testes as far as the median raphe, have interspersed amongst them numerous islets

of sclerosed tissue, in which the remains of degenerated medullary tubes are well seen. The whole sectional area of the fillet lying in *front* of the tegmentum was thus involved, but the tracts of grey degeneration were not extensive, being scattered apart, not in circular patches like distinct focal lesions.

The upper realms of the pons and medulla had unfortunately incurred such damage during the process of preservation as to preclude an exhaustive examination of the nuclei of origin of the remaining oculo-motor nerves.

In the case of A. B. we have all the symptoms of tabes dorsalis. There are pains sharp and sudden in character, an ataxic gait, absence of knee phenomenon, loss of pupillary reflex, loss of muscular sense, some cutaneous anæsthesia, gastric crises. But beyond these symptoms there is another of rarity and interest. The symmetrical immobility of the eyeballs accompanied by more or less ptosis of the lids is a condition which was first described by Graefe under the name of ophthalmoplegia progressiva. An account of it is contained in the 'Lehrbuch der functionellen Nervenkrankheiten,' by Eulenburg (Berlin, 1871). I can remember that, nine or ten years ago, shortly after reading that account, I saw an example of the disease in St. Bartholomew's Hospital. The patient was a female, under the care, I think, of Dr. Andrew, and she had this symmetrical immobility of the eyeballs typically marked. The disease has more recently received a most searching investigation at the hands of Mr. Hutchinson, who has applied to it the term ophthalmoplegia externa,* in contradistinction to that of ophthalmoplegia interna, which he had given in a previous paper, to a state of immobility of the pupil, in which the internal muscles of the eye (the iris and ciliary muscles) are together involved in paralysis. He, however, explains that the former term must be understood as including very frequently, if not usually, the immobility of pupil.

Mr. Hutchinson's description of the condition is so graphic that I cannot possibly do better than quote it here:—"Drooping of the eyelids," he writes, "so as to give to the face a half-

* 'Transactions Roy. Med. Chir. Soc.' 1879.

asleep expression, is usually the first symptom, and it is soon accompanied by weakness of all the muscles attached to the eyeball, so that the movements of the latter become much restricted, or even wholly lost. The condition is usually bilateral, though it is not always exactly the same in degree on the two sides. Its symmetry probably denotes that it is of central origin. It by no means always happens that all the ocular muscles are alike affected, or that they are attacked simultaneously, still it is a very marked feature of the malady that the muscles fail in groups and not singly." Seventeen cases of the kind are described in the paper. In ten of these it seemed certain that syphilis was the cause; in eight acquired, and in two inherited. Of the remaining seven Mr. Hutchinson remarks, "it may be said that a reasonable suspicion of syphilis might be entertained in several." In one case an examination of the brain after death was made by Dr. Gowers, who found that degenerative changes precisely similar to those seen in progressive muscular atrophy had implicated the origins of the third, fourth, and sixth nerves as well as, in that particular instance, the optic nerves also. The large nerve-cells had disappeared from the nuclei of origin of these nerves.

Mr. Hutchinson remarks that we have in such cases a very close parallel to the so-called bulbar paralysis—the labio-glosso-laryngeal paralysis of Duchenne—and he thinks it may be plausibly conjectured that the initial lesion is inflammation of the nuclei of the affected nerves, which, in a slowly serpiginous manner, creeps from place to place along certain definite anatomical paths. In my female patient the history of syphilis was clear and certain. On the other hand, there is no evidence that X. Y. had ever suffered from the infection. The condition of his aorta is a suspicious circumstance, but the history of rheumatic fever prevents us from laying stress upon the condition as indicative of constitutional syphilis. In any case, however, the proximate cause of the lesions of nuclei must be sought for in an extensively diffused disease of the vascular system, of which there is evidence in the dilatation of the aorta, the rigidity and tortuosity of the brachial arteries, no less than in the microscopical changes in the intrabulbar arterioles with the resulting miliary hæmorrhages.

In A. B. it will be observed there is a symptom which (as it happens) is not described as occurring in any of those related by Mr. Hutchinson. I refer to the atrophy of muscles about the back and shoulders. This association, however, evidently tends to support the view that the lesion of the nuclei of origin of the cranial nerves is probably of the same nature as that which determines progressive muscular atrophy. In Charcot's lateral amyotrophic sclerosis there is atrophy of the large motor cells in the anterior cornua of the cord. The disease tends, as we know, to travel upwards, and in time spreads to the medulla oblongata. Attacking there the nuclei of the hypoglossal, facial, and trigeminal (its motor portion), it causes death by involving also the nucleus of the vagus. Now, it seems probable that, were it not for the fatality necessarily attaching to the destruction of this nucleus, the disease would also, in those cases, be likely to invade the nuclei of origin of the oculo-motor nerves, and so bring about the condition of the eyes which is to be seen in this girl. Death, in fact, stops the progress of the disease before it invades the region devoted to the innervation of the external and internal muscles of the eye.

The lesion of nerve nuclei would appear, in the case of A. B., to be a more or less continuous one, from the intracranial centres for the higher cranial nerves to the anterior cornua of the cord. On the right side the origin of the facial nerve is involved, though not apparently on the left. The quivering of the tongue shows that the nucleus of the hypoglossal is probably not intact.

In the atrophy of the sternomastoids and left trapezius there is evidence of invasion of the nuclei of the accessory.

I have but little doubt that the gastric crises (as I have some time ago suggested[1]) depend upon irritation of the nucleus of the vagus by sclerosis. This opinion has since received support by the result of an observation of Pierret, who found in a case of tabes, with characteristic gastric crises, sclerosis of the fasciculus gracilis in immediate relation with the nucleus of the vagus. The fibres of the vagus and accessory are in such close proximity at their point of origin that chronic inflammation of

[1] Pathological Society, February, 1880.

the immediately adjacent tissues may be expected to cause both sensory and motor disturbance-pain in the stomach and vomiting.

The symptom of intense hunger, of which this girl complained, is one that I have on several occasions observed in connection with the occurrence of gastric crises in tabes. It was marked in a case of tabes with gastric crises and joint affection under the care of my friend, Mr. Herbert Page.

It is present also in the case of a man, suffering from tabes with gastric crises, who is now under my care in the hospital.

Only a few weeks ago, whilst looking through 'A System of Clinical Medicine,' by Dr. Graves, published in 1843, I chanced upon a description of gastric crises which is so graphic that I cannot refrain from quoting here a rather full abstract of the case narrated. Viewed by the light of our increased knowledge, the case is evidently one of tabes dorsalis, but it occurred long before this disease was differentiated from other forms of paraplegia. The autopsy, which included examination of the brain, spinal cord and nerves, besides the abdominal viscera, naturally failed to throw light upon the cause of the disease; for in those days the methods of hardening preparations of nerve substance, the initiation of which we owe to Lockhart Clarke, had not been devised, and the examination, as far as I can judge, was only made with the naked eye. Dr. Graves appears, however, to have been curiously near the true solution in a remark which he makes. "Are we to attribute," he writes, "this diseased condition of the stomach and bowels, which, from the remarkable periodicity of its occurrence, was evidently functional, to irritation, congestion, or inflammation of the brain or spinal marrow? From the data we are in possession of it appears that this question must be answered in the negative." He speaks of the case as a very remarkable one, which had made a great impression upon him, and, in his view, well worthy of the attention of the pathological inquirer.

The patient, Mr. B., aged 23, was exceedingly strong, and passionately fond of hunting, fishing and shooting. These habits, however, he laid aside after the occurrence of the first attack of his illness, which happened in 1829. From that time

his bowels, previously sluggish, became inclined to looseness, which always increased before the appearance of one of the attacks, accompanied by griping, nausea and inclination to vomit. Each attack was generally preceded by a copious secretion of insipid watery fluid in the mouth, and then the characteristic symptoms of his disease commenced. These consisted in obstinate and protracted nausea and vomiting. He first threw up whatever happened to be on his stomach at the time, and afterwards everything he swallowed, whether solid or liquid, and the quantity ejected in the course of a day varied from three to four quarts of fluid. He complained also of pain, referred to the stomach or lower part of the chest, which continued throughout the attack, being most acute at its commencement; for the last year this sensation had passed into a feeling of painful constriction, which he described as a "contracted feeling of his inside," and compared it to something like the effects of a cord drawn tightly, so as to compress or strangulate his body exactly along the outline occupied by the insertions of the diaphragm. During the prevalence of the attack he had profuse perspirations, particularly towards the termination of each paroxysm. The duration of the first attack did not exceed four or five days, after which he became quite well, and continued so for six or seven months, when his symptoms suddenly returned. He began to reject everything from his stomach as before, but in the course of a few days the vomiting disappeared, and for a considerable interval he had no return of his complaint. In the year 1830 he had three attacks of a similar description; from these he recovered also completely, and without remarking any diminution of power in his lower extremities. In 1831, however, the disease began to assume a more serious aspect; the paroxysms became much increased in severity, lasted longer and recurred at shorter intervals. For one of these attacks he took mercury, and was salivated. In 1832 his symptoms became still more violent, and the duration of the paroxysms more protracted. He had one in March, a second in May and a third in June, each of which was accompanied by some numbness and loss of power in the lower extremities; this, however, was slight, and disappeared altogether as the vomiting subsided. About this time

he noticed that his urine was scanty, and deposited more sediment than usual. He also complained of being very apt to catch cold whenever he got out of bed, and stated that he suffered occasionally from *severe twitches and pains in his legs, thighs, arms and other parts of his body*, which were generally succeeded and carried off by profuse perspirations.

In August, 1832, he had a violent attack, which lasted nearly a month. The vomiting was incessant, continuing night and day, and he suffered severely from the feeling of painful constriction already described. On getting up after this attack his legs suddenly failed him, and he dropped down on the floor quite powerless. The paralysis did not now disappear during the intervals, although it grew somewhat better after each fit of vomiting had ceased; indeed he used to improve in his walking after the paroxysm had entirely disappeared, and, aided by two sticks, supported himself so as to give some hopes of a recovery, until a recurrence of his attack reduced him again to a state of almost total paraplegia. His legs now began to waste sensibly, and he noticed that they had lost their feeling and were remarkably cold. He also complained of severe twitches of pain in various parts of his body, accompanied by profuse night sweats, and turbid scanty urine.

For some months before his death he was completely paraplegic, and continued to be attacked with violent fits of vomiting. The vomiting went on night and day, and he was unable to retain the mildest and most soothing substances for a moment on his stomach. Everything was tried to allay the irritability of the stomach, but in vain. After continuing to resist obstinately every form of treatment for five or six days and nights the vomiting would suddenly cease, the gentleman would exclaim, "Now I am well," and he could then eat with perfect impunity substances of an indigestible character. The transition from a state of deadly nausea and obstinate retching to a sharp feeling of hunger used to occur quite suddenly. One hour he was a miserable object, rejecting everything, and suffering the most painful constrictions across the epigastrium, the next found him eating with a voracious

appetite whatever he could lay hold of, and digesting everything with apparent facility.[1]

Here again we have the symptom of hunger described very graphically. I would submit that it tends to corroborate the view that the seat of lesion occasioning gastric crises is in the neighbourhood of the pneumogastric nucleus.

It may be asked why, if we have to do here with irritation of this nucleus, we should not, in cases of tabes with gastric crises, also meet with symptoms referable to the heart and to the respiratory apparatus. We do, in fact, sometimes meet with laryngeal crises, and rapidity of pulse is of no unfrequent occurrence in the course of tabes dorsalis. It does not seem reasonable, however, to expect that in these circumstances we should necessarily find evidence of impairment in all the functions subserved by the nerve.

It cannot be doubted, I think, that there is a very elaborate differentiation of functions of the nerve-cells constituting a nucleus. In a paper of great interest and importance[2] Dr. Felix Semon calls attention to the proclivity of the abductor fibres of the recurrent laryngeal nerve to become affected sooner than the adductor fibres, or even exclusively, in cases of undoubted *central* as well as peripheral injury or disease of the roots or trunks of the pneumo-gastric, spinal accessory, or recurrent nerves.

The differing amount of paralysis in the muscles of this girl's eyeballs and lids is also indicative of differentiation of function in various parts of the nuclei of the oculo-motor nerves.[3]

I do not think, therefore, that we shall see anything remarkable in irritation of the nucleus of the vagus in a particular case being followed by symptoms entirely referable to the stomach or intestines. Whilst upon this point I would remark that, in certain cases of tabes where the more typical form of gastric crises has not been marked, there has been,

[1] Several cases of typical gastric crises will be found described in my paper on "Certain Little Recognised Phases of Tabes Dorsalis," Transactions of the International Med. Congress, 1881.

[2] See 'Archives of Laryngology,' vol. ii. No. 3, July, 1881.

[3] Dr. Sturge has published some interesting remarks on this subject. "Two cases of simultaneous paralysis of both third nerves."—'Ophthalmological Society's Transactions,' vol. i.

nevertheless, a peculiar tendency not so much to diarrhœa as to abnormally frequent action of the bowels, the evacuations not being necessarily loose. I think it probable that this symptom, like the pain in the stomach and vomiting, may prove to depend upon irritation of the nucleus in question, for it must be remembered that the peristaltic action of the small intestine is largely influenced by nervous impulses passing along the splanchnic and vagus nerves. According to Pflüger, whilst stimulation of the splanchnic nerves tends to check the peristaltic movements, that of the vagus is calculated to excite them.[1]

In reference to this question of the dependence of gastric crises (of the two kinds which I have mentioned) upon sclerosis in the neighbourhood of the nucleus of the pneumo-gastric, I would call attention to a point which, although of purely negative character, seems to me to be of considerable importance.

The man X. Y. did not suffer at all from gastric crises. It will be observed that Dr. Bevan Lewis in this case found the nuclei of the vagus amongst other nerves well displayed and perfectly intact, and he adds, "no diseased tract of tissue was anywhere apparent in the transverse sectional areas of this district." The importance of this observation will be especially evident when it is remembered that the funiculus cuneatus and gracilis, which closely adjoin the sensory portion of this nucleus, represent the continuation upwards to the cerebellum through the medulla oblongata of the posterior columns of the spinal cord.

Let me note here an important difference in these two cases. The muscular atrophy which affects in a marked manner the trunk and extremities of the patient A. B., was entirely absent in the case of the man X. Y. The microscopical findings corresponded with the clinical history. (I ought here to say, perhaps, that I purposely kept Dr. Bevan Lewis in ignorance of the symptoms observed during life, in order that his observations might be quite unprejudiced.) Dr. Lewis reports that the anterior cornua of the spinal cord were entirely free from any morbid change.

[1] 'A Text-book of Physiology.' By M. Foster. 3rd edition, p. 267.

It is interesting to observe that Mr. Hutchinson found "in six of his cases the lower extremities more or less weak, and a condition approaching more or less closely to locomotor ataxy," and he makes the important remark, that "there can be no doubt that ophthalmoplegia externa is sometimes a part of the general malady known as progressive locomotor ataxia, especially when that disease is due to syphilis." The two instances which I have described are examples, at all events, of the first described association. Both patients presented the most characteristic symptoms of tabes dorsalis. In each there were "lightning" or "electric" pains, absence of knee phenomenon and ataxy. No other signs need mention in the presence of these.

ON THE CONDITION OF THE KNEE-JERK, ANKLE-CLONUS, AND PLANTAR REFLEX AFTER EPILEPTIC FITS IN SEVENTY CASES; AND ON POST-EPILEPTIC CONJUGATE DEVIATION OF THE EYES.

BY CHARLES E. BEEVOR, M.D. LOND., M.R.C.P.,

Late Resident Medical Officer to the National Hospital for the Paralysed and Epileptic.

THE presence of ankle-clonus and excessive knee-jerk (patellar tendon reflex) after epileptic fits was first pointed out by Dr. Hughlings-Jackson in a case of unilateral convulsions, which was recorded by him in the 'Medical Times and Gazette' for February 12th, 1881.

While I was Resident Medical Officer at the National Hospital for the Paralysed and Epileptic, Queen Square, I was asked by Dr. Hughlings-Jackson, and also by Dr. Gowers, to make observations as to the presence of ankle-clonus and the knee-jerk after epileptic seizures, and the following results were obtained by personal observation of seventy fits occurring in thirty-one different patients. I have to thank the physicians under whose care these cases were, for allowing me to record the following observations.

To obviate as much as possible any source of error, I took myself, or dictated, notes at the time, and directly afterwards copied them out in full. The knee-jerk was tested with a heavy vulcanite stethescope, with a ring of india-rubber round the disc, as advised by Dr. Buzzard, instead of trusting to the rougher method by striking with the edge of the hand.

The plantar reflex was tested by a sharp quill-pen, and the ankle-clonus was tried with the knee at various angles, as it

is obtained best with different degrees of tension of the calf-muscles.

The cases have been divided into those which were observed *instantly*—where the whole of the fit was observed, or at least the end of the clonic stage was witnessed—and into those which were seen *directly*, where perhaps 1 to 2 minutes might have elapsed, but always before the patient showed any signs of returning consciousness. The time at which the various phenomena showed themselves or disappeared was taken by a watch, and the probable duration was not roughly guessed at.

The cases may be arranged in a table:—

	Seen instantly after Clonic Stage.	Directly after Clonic Stage.	Total.
Knee-jerk increased and ankle clonus present	27	11	38
Knee-jerk diminished, ankle clonus absent	6	7	13
Knee-jerk absent, ankle clonus absent	3	8	11
Knee-jerk normal, no ankle clonus	4	1	5
Knee-jerk diminished, ankle clonus present	2	0	2
Knee-jerk normal, ankle clonus present	1	..	1
Total	43	27	70

In all the above cases the phenomena were obtained on both legs.

In all these cases the plantar reflex was absent instantly after the clonic stage, but it returned in from 3 to 13 minutes, the average time being about 5 minutes; the time at which the ankle-clonus passed off was also noted by a watch, and seemed to correspond to the time of return of the plantar reflex, and in 10 out of 15 cases in which the times of the disappearance of the ankle-clonus and the appearance of the plantar reflex were taken, it was found that the two coincided approximately.

In one of the cases seen instantly, in which the knee-jerk was increased, there was no ankle-clonus.

In one of the cases in which the knee-jerk was diminished

and there was no ankle-clonus when tried instantly, in 6 minutes the former became excessive and the latter was also well obtained; and in two cases where the knee-jerk was diminished, when observed directly after the clonic stage, it was found to be increased in a few minutes.

Of the three cases where both phenomena were looked for instantly and were absent, one was doubtful, and in the eight observed directly two were doubtful, and in one the knee-jerk was present in 5 minutes' time, while in another both phenomena were very well obtained in 8 minutes. The two apparently anomalous instances of the presence of ankle-clonus and diminution of the knee-jerk were observed twice in the same patient.

In all the above cases, the fits were ordinary bilateral epileptic attacks, beginning as a rule with rotation of the head and turning of the eyes towards one side, and in some of the attacks the ankle-clonus and the knee-jerk were decidedly more active after the clonic stage on the side to which the initial rotation of head and eyes occurred.

In the intervals of ordinary bilateral attacks the knee-jerk is usually obtained on both sides more readily than normally, but there is no ankle-clonus.

Besides the foregoing observations on the knee-jerk and ankle-clonus after epileptic fits, I have also had the opportunity of observing another phenomenon, viz., conjugate deviation of the eyes occurring instantly *after* the clonic stage of the fit is over.

A short notice of this phenomenon was given in the 'British Medical Journal' for January 21st, 1882; but I propose to give a fuller account of it in this paper. The explanation of it will, I believe, be better obtained by drawing an analogy between this phenomenon and the conjugate deviation of the eyes which is a known symptom in some cases of recent hemiplegia.

In cases of hemiplegia, after a recent lesion in one hemisphere, the symptom of conjugate deviation of the eyes and rotation of the head to one side is frequently noticed, by which it is meant that the head and eyes are turned towards the same side as that half of the brain in which the lesion is situated, and consequently away from the side of the limbs and face which are the seat of paralysis, so that a lesion in the

left hemisphere causes paralysis of the right side of the body, and conjugate deviation of the eyes and rotation of the head to the left. This symptom has been explained by the theory that the muscles of the eyes on the paralysed side—the right in our supposed case—are unable to antagonise and prevent the healthy muscles from drawing the eyes in a parallel manner towards the unaffected side, i.e. the left. I have not been able to find out that any previous observations have been made with regard to the presence of conjugate deviation of the eyes *after* epileptic fits. My attention was first drawn to the point by a case of Dr. Gowers' that I saw at the patient's own home; the man had had thirty or forty fits in about twelve hours, and when I saw him he had marked conjugate deviation of the eyes and rotation of the head to the left; the fits, his friends assured me, began with turning of the head and eyes to the right and the convulsions were right-sided. As soon as the fit was over the head and eyes turned to the left and remained there till the next fit, when they again turned to the right, to again assume the position to the left after it. It then occurred to me that I ought to find conjugate deviation of the eyes or rotation of the head in ordinary bilateral epileptic fits, for one side of the body is nearly always affected more than the other. I have looked for these phenomena in every case since, and I have taken notes at the time to obviate any source of error.

In an ordinary epileptic fit the tonic stage usually (if not invariably) begins by rotation of the head and turning of the eyes to one side—say to the right—and sometimes with flexion of the elbow and wrist of the same side as that to which the head turns. This tonic spasm is followed by clonic spasm, in which, perhaps, the two sides of the body are convulsed apparently equally. Directly all movement has ceased, and the patient lies with the limbs relaxed, the eyes will be noticed to roll slowly over to the opposite side—which in our supposed case would be to the left—and they remain there from ½ to 2 minutes. In thirteen consecutive cases where this post-epileptic deviation has been looked for, I have noticed it in eleven, and in one case the eyes have simply gone back to their natural position and have not passed to the opposite

side; in only one case have the eyes remained in the same position in which they turned in the primary tonic spasm, and this was a very slight fit. The *head* either remains in the same position as it assumed during the attack, or returns to the front. I have not yet seen the head rotate to the opposite side, after the end of the clonic stage, in universal bilateral fits, though I have witnessed it in a unilateral attack.

It is known that paralysis (either transient or permanent) occurs after some epileptic attacks, and most commonly in unilateral fits; the presence of any paralysis in an ordinary epileptic fit cannot be ascertained, for the reason that, by the time that the patient has recovered sufficient consciousness to use the dynamometer, the paralysis has passed off. I believe that the presence of the conjugate deviation of the eyes shows that the side where there is the primary discharge, and on which, presumably, the spasms are more severe, becomes more exhausted than the side where there is less discharge, and the eyes are drawn to the side where the muscles are the less exhausted. The head does not rotate, for the reason, I believe, that there is not sufficient difference of power between the two sides to affect this, while the eyes being very mobile are very exact indicators of the difference in the paralysis of the two sides.

In one patient of Dr. Ramskill's, the head and eyes first turned to the right, she was then clonically convulsed on both sides of the body, and while the clonic spasms were continuing the head and eyes went to the left; after all movement had ceased, the eyes and head rotated back again to the right and remained there for a few seconds; the head then turned straight and then the eyes rotated from side to side, keeping parallel; thus seeming to show that the side on which the discharge last occurred was the more paralysed directly after the clonic stage, and not necessarily the side where the primary discharge took place.

Another phenomenon which I have observed is, that, after the conjugate deviation has lasted for ½ to 2 minutes, the eyes sometimes—for 10 minutes—roll slowly from side to side, keeping parallel, and they also seem to wait longer on the side towards which they first conjugately deviated; during this time the pupils frequently oscillate. Perhaps this may be

explained by an irregular return of power and recovery from exhaustion in the two hemispheres of the brain, the one predominating over the other in turn. I have observed this rolling of the eyes from side to side in about half the cases in which it was looked for.

The foregoing post-epileptic phenomena, I think, seem to show that there is a great similarity between the state immediately following an epileptic fit and the condition which is found in a case of recent hemiplegia, a fact which has frequently been pointed out before in unilateral fits, in which temporary paralysis of the affected side is not uncommon. I believe the same analogy can be applied to *all* bilateral epileptic fits; for in these last there is usually, instantly after the clonic stage, deviation of the eyes, increased knee-jerk and ankle-clonus, and absence of the plantar reflex, and it seems probable that the same condition which produces permanently in cases of hemiplegia these phenomena, viz. excessive knee-jerk, ankle-clonus, and absence of superficial reflexes, is also present, though for a much shorter period, i.e. for a few minutes, directly after epileptic attacks, and when these are bilateral the above phenomena are obtained on both sides, with the exception that the post-epileptic deviation of the eyes occurs towards the side of less paralysis.

It would seem, therefore, that, after an epileptic seizure, the brain and spinal cord are reduced, probably by exhaustion due to the excessive motor discharge, to the condition which is obtained in cases of hemiplegia, for in both there is usually excessive knee-jerk and ankle-clonus and absence of plantar reflex. In reference to the latter, I have had the opportunity of observing, in a case mentioned by Dr. Gowers in his work on epilepsy, where the patient was clonically convulsed on the right side for 20 minutes (by the watch), that the knee-jerk was more marked instantly after on the right than on the left, and the plantar reflex was obtained on the left side in 3 minutes after all movement had ceased, but that on the convulsed side—the right—it was only obtained slightly in 30 minutes' time, and in this case there was paralysis of the right side, from which he did not recover till an hour or two later, speech being also affected.

THE BRAIN OF A CRIMINAL LUNATIC.

BY DAVID FERRIER, M.D., F.R.S.

THE brain figured and described in this paper was put into my hands for examination by Dr. Nicolson, of Broadmoor Criminal Lunatic Asylum.

It was the brain of a woman who in 1871 murdered two of her children, but who, on being arraigned on a charge of murder, was found insane and incapable of understanding the charge against her. She was therefore ordered to be confined during Her Majesty's pleasure.

From the notes supplied by Dr. Nicolson, the following are the main facts which were ascertained in regard to the woman's history and condition:—

She was forty-four years of age at the time of her death, which occurred in November 1881. Her mother states that she was very intelligent as a child and young woman, was well educated for one in her position, and married a labourer when she was thirty years of age.

After the birth of her first child she became paralysed on the right side and aphasic. This was about 1868, the exact date not being obtainable.

In October 1871 she strangled her two children, aged two years and eight months respectively.

In March 1872 she was sent to the Criminal Lunatic Asylum at Broadmoor, under the circumstances already mentioned.

On admission she was hemiplegic on the right side, the right arm being described as almost powerless, but she was able to use the right leg feebly in locomotion without any assistance, though, as a rule, she helped herself forward with the left hand.

The right side had not lost sensibility, but she complained of the whole of this side being cold, and she always kept it specially wrapped up on this account.

For some months after her admission she was subject to flushings, faintness, and occasional convulsions of a slight character accompanied by vomiting.

Towards the end of 1873 epileptiform convulsions became more marked, and she had repeated attacks of dulness and torpor of intellect, with flushing of the face.

Fits continued with more or less prolonged intermission, and she had a series of severe attacks in May 1877. In the severe fits the convulsions were of a general character. Her head and eyes were drawn to the right, and there was complete insensibility. In the slighter fits the eyes were directed to the right, with momentary unconsciousness, but there was no general muscular spasm. From May 1877 up to the time of her death there were no severe fits, but she showed from time to time twitchings of the facial muscles.

She had repeated attacks of pyrexia and flushing, with pain in the head, especially localised in the left temple. The pain was always relieved by a few leeches to this spot, and she usually brightened up after their application, and would signify her desire to have leeches applied when the pain was severe.

Her disposition was very fitful and uncertain. As a rule she was well-disposed and almost cheerful, and frequently exhibited much gratitude for any services done her.

On many occasions, however, she was petulant, irritable and cross with the other patients. When in this state she was quite silent, and sometimes mischievously tried to break windows. Sometimes she was very melancholic and refused food for days. A few months before death she was found attempting to injure herself by dashing her head against a water-tap.

Her conversation was of a jerky, monosyllabic character, and always an evident effort to her. She would frequently forget the word she wished to use, but could indicate by gesticulation when the right word was named to her.

If anything she wished for were granted to her, her face lit

up and she would say, "Thank you kindly, mum," (and then correcting herself), "sir." She could not always correct herself, and then appeared confused. She made use of certain stereotyped phrases, and the usual conversation might be given as follows:—

"Good morning, Mrs. P." *A.* "Goo' mornin', mum,—sir." "Any pain to-day?" *A.* "Yes; pain—always pain." If she did not feel well she would say "bad," and then pointing to her right side, "Cold all down." If more than usually depressed she would say, "Wish were dead!"—"Paralsee long time, 'ome two year, Bo'moor eight." She would then burst into tears and sob piteously.

In July 1881 she became very obstinate and silent, and refused food. At this time her respiration became difficult, and there were marked signs of phthisis in both lungs, especially the right; œdema of the legs set in, and she gradually failed, and died in November 1881.

On post-mortem examination the lungs were found extremely tubercular, numerous cavities existing in the right, which was almost entirely disorganised.

The skull cap was dense, but there was no apparent want of symmetry on the two sides.

Condition of the Brain.

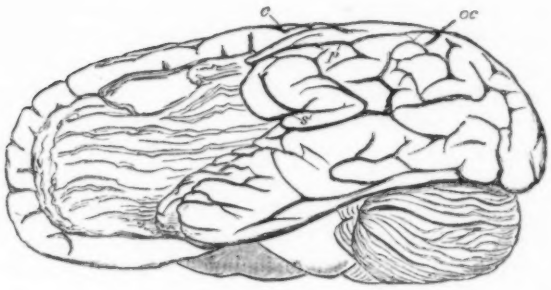
The *right* hemisphere was well developed and normal in the arrangement of the fissures and convolutions.

The *left* hemisphere had a strikingly abnormal aspect.

The general outline was smaller than that of the right, so that viewed from the left, as seen in Fig. 1, the internal surface of the right hemisphere was visible in the frontal, parietal and sphenoidal regions. The occipital surface, however, was entirely covered by the equally well-developed occipital lobe of the left hemisphere.

The anterior half of the left hemisphere was represented by an empty cyst (which was full of fluid at the time of removal), the walls of which were collapsed and puckered. The posterior boundary of this cyst was formed by a line drawn almost perpendicularly from the upper extremity of the fissure of

Fig. 1.



Rolando (indicated on the right hemisphere by *a*, Fig. 1) into the horizontal limb of the fissure of Sylvius, which formed the rest of the boundary. The posterior extremity of the fissure of Sylvius (*s'*, Fig. 1) was still visible. In advance of the line indicated, the whole of the cortex and medulla was entirely deficient, both on the convexity and on the orbital aspect of the frontal lobe.

The island of Reil was also entirely absent.

On the internal or median aspect of the frontal lobe, however, the gyri and sulci were distinct and normal in arrangement, though somewhat smaller than on the right.

The *gyrus fornicatus* was normal from its commencement at the anterior perforated space to its posterior termination in the *gyrus hippocampi*, which with its *uncus* was well developed. Above the calloso-marginal sulcus the marginal aspect of the hemisphere was formed by the median surface of the superior frontal convolution and the paracentral lobule, not so well developed, however, as on the right. The *præcuneus* or quadrilateral lobule, the *cuneus*, the internal aspect of the occipital lobe, and the occipito-temporal convolutions were all of normal appearance.

On the convex aspect of the posterior half of the left hemisphere which remained, the parieto-occipital fissure (*o c*, Fig. 1) was well marked, and extended fully half an inch outwards from the longitudinal fissure. The convolutions of the occipital lobe posterior to this fissure, and its imaginary continuation to the *incisura præoccipitalis*, were well developed.

Between this line and the boundary of the atrophied region, the convolutions and fissures had suffered considerable displacement, owing chiefly to the great diminution of the postero-parietal or superior parietal lobule.

The intra-parietal fissure (Fig. 1) was found to commence at the posterior boundary of the cyst and to pursue a course almost parallel to the median fissure, the greatest distance between the two being only 1 centimetre. The distance anteriorly was rather less, as at this point the lobule tapered somewhat.

The postero-parietal lobule included between the longitudinal fissure and the intra-parietal sulcus was thus, as compared with that of the right hemisphere, greatly reduced in size. On the sound side the greatest width between the longitudinal fissure and the intra-parietal sulcus was 4 cent., and nowhere less than 2 cent.

The posterior or upper extremity of the horizontal limb of the fissure of Sylvius (*s'*, Fig. 1) was situated 2 cent. below the anterior extremity of the intra-parietal sulcus.

The portion of the cortex remaining between these two points corresponded to the anterior extremity of the angular gyrus or portion of the supra-marginal lobule. This was continuous round the extremity of the fissure of Sylvius with the superior temporo-sphenoidal convolution, of which only 2 cent. of the upper extremity remained. The rest was atrophied and its position taken by transverse gyri, which ran obliquely from the middle temporo-sphenoidal convolution into the fissure of Sylvius. The angular gyrus was somewhat smaller than on the right side. The upper or posterior half of the middle temporo-sphenoidal convolution was normal. The lower half was atrophied and sloped obliquely forward into the fissure of Sylvius.

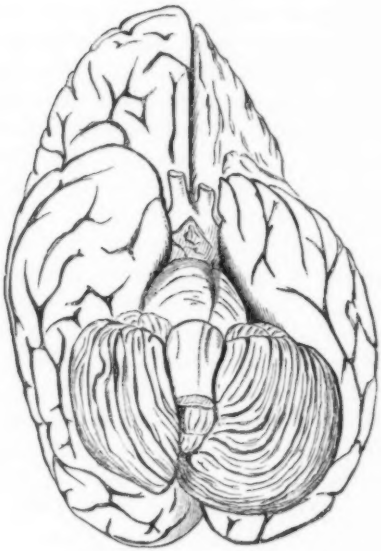
The inferior temporo-sphenoidal convolution was normal.

It will be seen, therefore, that there was *total absence* of the *superior frontal* (median aspect excepted), *middle frontal*, and *inferior frontal* convolutions, the *island of Reil*, the *ascending frontal* and *ascending parietal* convolutions. Also of the *anterior three-fourths of the superior temporo-sphenoidal*, and *anterior half of the middle temporo-sphenoidal* convolutions.

In addition there was *considerable atrophy* of the *postero-parietal lobule*, and to some extent also of the angular gyrus.

The *base of the brain* had a remarkable appearance (Fig. 2).

Fig. 2.



The median fissure was bounded on the left by the internal margin of the orbital lobule, but all external to this looked as if it had been sharply cut off.

The anterior extremity of the temporo-sphenoidal lobe of the left side, instead of the rounded full appearance of the right, was somewhat flattened and sloped obliquely into the Sylvian fossa.

The optic chiasma and optic tracts had a skew appearance, the right being anterior to the left. The corpora mammillaria were similarly displaced, the left being considerably posterior to the right.

The right *crus cerebri* stood out prominently, but the left was sunk and invisible except when the parts were separated. The left optic tract had a greater obliquity than the

right, and was visible to a greater length in its course round the crus.

The foot of the left crus cerebri was atrophied in its inner two-thirds.

The locus niger was only 1 m. from the surface, except at the outer third, where the fibres of the foot formed a layer of 5 mm. The depth of the locus niger of the right crus from the surface was throughout fully 5 mm.

A marked asymmetry was visible in the *pons Varolii*.

The groove indicating the middle line had a tortuous direction, owing to the great flattening and obliquity of the left half. On cross section the pyramidal tracts were of a greyish tint and sclerosed.

The left olivary body appeared more prominent and nearer the middle line of the medulla oblongata than the right.

This was owing to the almost complete disappearance of the left pyramidal tract. The right pyramidal tract at the middle of the olivary body had a breadth of 5 mm., while the left measured only 2 mm.

The left lobe of the *cerebellum* was of normal size, but displaced, so that it projected across the middle line and rested on the under surface of the right occipital lobe. This was due to atrophy of the right lobe of the cerebellum, which was reduced to about half the size of the left lobe.

The cortical laminæ were thin and the leaflets of the *arbor vitæ* smaller than those of the other side.

Microscopical preparations of the cerebellum made for me by Dr. Scott, and taken from the cuneiform lobe of each side, including portion of the nucleus dentatus, exhibited a remarkable degree of atrophy of the cortex of the left side.

The outer or grey layer was greatly reduced in thickness and Purkinje's cells had entirely disappeared, in some leaflets entirely, while in others only portions had become so atrophied.

Dr. Scott's measurements of twenty specimens gave the average thickness of the grey layer as 3·3 thousandths of an inch, while on the sound side this layer measured 15 thousandths of an inch and exhibited the cells of Purkinje in a beautiful manner.

The granular layer was also greatly reduced. The average thickness of this layer on the sound side was 7 thousandths of an inch, whereas in the atrophied regions of the left cortex the thickness was only 1 thousandth of an inch.

The cells of the nucleus dentatus were unaltered in appearance.

The superior peduncles of the cerebellum, and the *corpora quadrigemina* were normal in appearance, and no difference was appreciable between the right and left. The inferior peduncles of the cerebellum were also of a similar appearance on the two sides.

There was, however, a marked difference between the middle peduncles. The right middle peduncle was considerably smaller than the left. At the point of junction with the pons the vertical diameter of the left peduncle was 1·3 centimetre, and of the right only ·8 cent.

On division of the *corpus callosum* in the middle line, this commissure was found to be greatly atrophied, and to form merely a thin membrane along the internal aspect of the hemisphere corresponding to the atrophied region of the convexity. Posteriorly, in the region of the *splenium*, the two sides had a similar thickness.

The pillars of the *fornix* were distinct and equal on the two sides, on the left side almost free from the *corpus callosum* throughout.

The left anterior pillar descended somewhat posterior to the right. Between the two the anterior commissure was of normal size, though slightly oblique.

The posterior commissure, pineal gland, and its peduncles were normal.

The soft commissure was particularly distinct. It crossed the third ventricle somewhat obliquely, the left extremity being a little posterior to the right.

There was no trace of the *nucleus caudatus* or *lenticularis* in the floor of the left lateral ventricle. The floor consisted only of thin membrane forming the orbital aspect of the cyst, which also formed the lateral and superior wall of the ventricle.

The left optic thalamus was smaller than the right.

The anterior extremity of the thalamus began abruptly in a line with the anterior margin of the soft commissure, so that the left seemed smaller than the right by all in advance of this line. The posterior two-thirds of the left thalamus were well developed, and only apparently smaller than the right by the flattening and depression of the left crus cerebri. The *pulvinar* and *corpora geniculata* were equally distinct on both sides.

The left wall of the third ventricle appeared to pass uninterruptedly into the *gyrus fornicatus*.

From the anterior extremity of the left optic thalamus a medullary lamina ·5 cent. width at its junction with the thalamus ran forwards, parallel to the wall of the third ventricle, and lost itself in the marginal region of the frontal extremity.

From the posterior third of the optic thalamus a medullary lamina, measuring 1·5 cent. in width at the edge of the thalamus, radiated outwards towards the occipital and temporo-sphenoidal regions. Between the anterior and posterior medullary laminæ thus marked off, there was a space formed only by the membranous wall of the cyst, entirely devoid of medullary fibres, measuring 1 cent. at the margin of the thalamus, and extending outwards in fan shape towards the atrophied region of the cortex.

Remarks.—This case is in many respects a remarkable one. Though the history is not in all points so complete as could be wished, there is sufficiently clear evidence that up to the age of thirty the woman was to all appearance perfectly well bodily and mentally. Yet such a complete destruction and disappearance of all trace of cerebral tissue had occurred as is met with usually only in congenital cases, and regarded by older writers as due to agenesis or defective development and not to morbid processes. There can be no reasonable doubt, however, that in this case the complete disappearance of such a large extent of the cortex and of the corpus striatum must have been consecutive to some morbid process occurring in adult life, probably embolism of the left middle cerebral artery. The area of distribution of this artery coincides very closely with the regions which have totally disappeared—viz.,

the artero-lateral branches supplying the corpus striatum, and anterior part of the optic thalamus, and the five branches to the convex aspect of the hemisphere, as described by Duret, viz. the external and inferior frontal, the anterior parietal, the posterior parietal, and parieto-sphenoidal arteries.

Considered in reference to the symptoms, the condition of the brain is entirely in harmony with them, according to the doctrines of localisation maintained by myself and others.

With the exception of the postero-parietal lobule, which was greatly reduced in size, and the median aspect of the ascending convolutions, or paracentral lobule and its neighbourhood, the whole of the motor centres of the left hemisphere had disappeared.

In accordance with this, there should have been, theoretically, weakness, but not absolute paralysis, of the right leg, total paralysis of the right hand, with the retention of some of the movements of the upper arm, and paralysis of the right side of the face. This was the condition actually existing.

There should have been also—for a time at least—deviation of the head and eyes to the left, but on this point the history is defective.

And in accordance with the immense majority of instances there should have been complete aphasia or speechlessness. That aphasia existed at first is certain, but the history is defective as regards exact details.

The recovery from the condition of absolute aphasia took place to a considerable extent, though speech was permanently very defective and confined to a few simple phrases and monosyllables. Though in most cases of recovery from aphasia the restoration is due to the fact that the speech-centres of the left hemisphere are not permanently or completely destroyed, yet a case like this seems to bear out the view that compensation may be effected by the speech centres of the other hemisphere. For in this case not a trace of these remained in the left hemisphere. The compensatory action of the right hemisphere was illustrated by a similar case reported by Batty Tuke and Fraser,[1] in which, though Broca's convolution

[1] 'Journal of Mental Science,' April 1872.

in the left hemisphere was entirely destroyed, the aphasic condition, which at first existed, became considerably ameliorated. The present case seems to me thoroughly to substantiate such a compensatory action on the part of the right hemisphere, as always a possibility, if not always an actuality.

That there was no loss of sensibility on the right side shows that the regions destroyed are not the centres of sensibility, and that these, both general and special, are situated in the regions posterior to the fissure of Rolando and fissure of Sylvius, as I have elsewhere demonstrated.

The partial destruction of the auditory centre does not seem to have caused any permanent "word-deafness," as the patient seemed always readily to understand what was said to her. What the condition was in the earlier stages is unfortunately impossible to ascertain accurately.

The mental condition of the patient was profoundly impaired, a condition in which the total destruction of the anterior frontal regions on one side, no doubt, played an important part, as has been demonstrated by recorded cases of lesions invading this region alone. But the case is too complex to allow of an exact estimation of how much is to be attributed to the degeneration of this region.

Considered in reference to cerebral anatomy, the case may be regarded as a functional dissection of the motor tracts and their connections.

Secondary to the destruction of the motor area of the cortex and internal capsule with its nuclei, we have a marked degeneration of the inner two-thirds of the foot of the crus cerebri, which are thus shown to be in direct relation with the atrophied regions.

The remarkable degree of atrophy of the right lobe of the cerebellum is also an important fact. Atrophy of the opposite lobe of the cerebellum has been recorded in many instances of degeneration more or less extensive of one cerebral hemisphere. Numerous cases of this kind have been described and referred to by Cotard,[1] and others have been recorded by Howden,[2] Schroeder van der Kolk, &c. But this case seems

[1] 'Atrophie Partielle du Cerveau,' 1868.

[2] 'Journal of Anatomy and Physiology,' May 1875.

to show with unusual precision atrophy of the cerebellum in relation with degeneration confined to the motor region of the opposite cerebral hemisphere.

Of the peduncles of the cerebellum, the right middle peduncle alone exhibited evident signs of atrophy. In connection with this there was great flattening of the left side of the pons.

This condition is altogether in harmony with Meynert's view, that the middle peduncles of the cerebellum are in relation with the pyramidal tracts of the opposite cerebral hemispheres respectively. Meynert has appealed to such cases of crossed cerebellar atrophy in support of his anatomical views, but their validity has been disputed by some. Gudden has not found that destruction of one hemisphere in animals causes any discoverable atrophy of the opposite cerebellar hemisphere.

But the experimental conditions were probably not such as to allow of time for the atrophy showing itself; for there seems no reasonable ground of doubt for regarding the atrophy of the right cerebellar lobe, so evident in this case, as in direct relationship with the destruction of the motor region of the left cerebral hemisphere.

The atrophy of the cortex of the cerebellum, both the grey layer with the cells of Purkinje, and the granular layer, taken in relation with the atrophy of the middle peduncle, shows the direct anatomical relationship of this peduncle with the cortex, and the functional association of these parts with the cerebral motor centres and tracts.

Only a very small portion of the pyramidal tract of the left side of the medulla oblongata remained, and if the spinal cord had been available for examination, degeneration of the pyramidal tracts would without doubt have been readily demonstrable.

METHODS OF PREPARING, DEMONSTRATING, AND EXAMINING CEREBRAL STRUCTURE IN HEALTH AND DISEASE.

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(Continued from p. 466.)

Staining and Mounting Sections of Hardened Brain.

THE staining reagents advocated by different authorities for sections of the nervous system prepared by hardening are numerous, and the list has become so lengthened since the earlier labours of Lockhart Clarke, Van der Kolk, and others, that one great difficulty presented to the student is to make a judicious selection of such as will yield him the best results in the special direction pursued by his work. Amongst those most generally used are carmine and its combinations—picro-carmine, indigo-carmine, and borax-carmine; the aniline series comprising aniline blue-black, aniline blue, methyl-aniline, and rosanilin or magenta; hæmatoxylin or logwood; eosin; picric acid; osmic acid; double chloride of gold and potassium.

Many years' experience has convinced me that a large proportion of these reagents may be safely dispensed with, the following list really comprising all the more essential solutions for staining nervous tissues.

List of Staining Reagents. — Hæmatoxylin, carmine in ammoniacal solution, picro-carmine, aniline blue-black, aniline blue and osmic acid.

In making choice of metallic impregnation by osmium or staining by means of the mineral or vegetable pigments in this list, the student must be influenced by several considera-

tions. Does he require a uniform staining by a simple dye, or does he wish for a differentiation of elements by the use of double pigments, or by double staining? Does he wish to examine specially the cortex and medulla of the cerebrum, or the cortex of the cerebellum; or again, the pons, medulla, and cord? Does he desire to display certain special elements of the cortex, e.g., the nerve-cells and their extensions to their greatest advantage, even at the sacrifice of other details, such as is often required in minute investigations into the histological constitution of the tissues?

Whatever be his object, these questions must receive an answer before the staining reagent can be selected which will yield the effect desired. I propose to give here the composition of each reagent, the method of staining, and its special value as a dye for the various histological elements, and supplement these observations by an analysis of their relative value for different regions of the cerebro-spinal system.

Hæmatoxylin or Logwood Staining.

This reagent has often fallen into disrepute owing to the notable variability in the quality of the dye issued by different makers. It is always advisable to make our own solution, adopting the formula given by Minot, or that employed by Kleinenberg. For the brain and spinal cord I use the former, as it is preferable to that of Kleinenberg, and I find it at all times most trustworthy in its reaction, and the uniformity of results obtained.

Minot's Formula.

Hæmatoxylin (crystals)	3·5 parts
Absolute Alcohol	100 „
Alum	1 „
Water	300 „

First dissolve the hæmatoxylin in the alcohol, and add to it the alum previously dissolved in the water. Keep in a stoppered bottle labelled "Hæmatoxylin Dye" (Minot).

For use—a solution of alum (0·5 per cent.) is poured into a watch-glass or porcelain capsule, according to the size and number of the sections to be stained; a little of the dye is

then dropped in until the solution assumes a light violet tint, when it should be passed through filtering paper before the sections are immersed in it. The degree of dilution will soon be learnt by experience, the depth of tint being our guide.

Kleinenberg's Formula.

1. Make a saturated solution of crystallised calcium chloride in 70 per cent. alcohol, and add alum to saturation.
2. Make a saturated solution of alum in 70 per cent. alcohol, and add 1 to 2 in the proportion of 1 : 8.
3. To the mixture of 1 and 2 add a *few* drops of a *barely* alkaline saturated solution of hæmatoxylin.

Excellent as this logwood solution is for embryonic tissues, I cannot recommend it for the sections of hardened brain such as we are now engaged with, to the same extent that I can that of Minot.

The Staining Process.—Withdraw the sections to be stained from the methylated spirits in which they float by means of a glass rod or camel-hair pencil, and immerse them in the logwood dye contained in a watch-glass or porcelain capsule. The sections should be lightly stained, otherwise they are spoilt, both by too diffuse a staining and by acquiring a brittleness unfavourable to subsequent manipulation. In his first attempts the student should occasionally examine a section on the stage of the microscope, and so judge of the progress made by the staining. When sufficiently stained the dye should be poured off, the sections floated up in a porcelain capsule half full of water, the capsule slightly inclined towards a gentle stream of water from a tap which, falling on the edge of the capsule, keeps up a constant change of fluid, and ensures a most thorough washing of the sections by the currents it produces. Care should be taken that delicate sections are not torn by this means, which is really necessary to ensure removal of all deposit from their surface. Next remove the section to a capsule containing methylated spirit, which, after one or two hours' immersion, will have deprived them of any diffuse staining. They are placed in rectified spirit or absolute alcohol for five or ten minutes for dehydration, transferred to

the centre of a glass slide, floated up by a drop or two of oil of cloves, which is allowed to run beneath them, and, when perfectly transparent, the oil is drained off, and the section mounted in Canada balsam. To ensure successful staining with this reagent, the following points must be carefully attended to:—

Stain only the very finest sections.

Let the sections be perfectly freed from any acidity due to chromic or picric acids, &c., by immersion in spirit, otherwise the staining will be a failure.

Make your own solution of hæmatoxylin.

Employ Minot's solution in preference to others, and reserve Kleinenberg's for embryonic brain.

Never omit filtering the diluted dye prior to use.

Guard against diffuse staining and brittleness from too prolonged action of dye.

Wash the sections *very thoroughly* subsequent to staining.

Remove any accidental diffuse colouration by prolonged immersion in alcohol.

Dehydrate perfectly before clearing up with clove oil.

Mount in a benzole solution of balsam.

Notes on the Reaction of the Dye.—Hæmatoxylin is especially well suited for the display of the various nuclei met with in the brain and spinal cord, e.g., the connective nuclei of the neuroglia, the peri-cellular and peri-vascular nuclei; the nuclei and nucleoli of the nerve-cells. The large nerve-cells of the cortex are beautifully shown in successful preparations, and their primary and secondary branches may be followed for some distance, but never to the extent seen in aniline staining. On the other hand, both neuroglia basis and nerve-structures undergo much shrinking by the use of the dye, and from this cause the smaller cells of the upper layers lose, to a great extent, their normal features. The protoplasmic extensions and nerve-fibre network of the cortex are, indeed, very poorly exhibited in logwood as compared with aniline preparations. The axial cylinders of medullated fibres exposed in transverse section are well exhibited by logwood, and hence sections of spinal cord and medulla stained by this dye show to advantage.

Carmine Staining.

The Dye.—The most useful solution for hardened brain sections is that recommended by Beale, which can be diluted to the required strength, the original solution being far too strong for our purpose.

Beale's Formula.

Carmine (in small fragments)	10 grs.
Price's Glycerine	2 oz.
Strong solution of ammonia	½ drachm.
Alcohol	½ oz.
Distilled water	2 oz.

Agitate the carmine with the liquor ammoniæ in a test-tube gently heated over a spirit-lamp. The solution when completed is carefully boiled for a few minutes, and exposed in the open test-tube for one hour for the escape of excess of ammonia. The water is now added, the solution filtered, and, after the addition of the spirit and glycerine, it must be exposed to the air until the odour of ammonia given off from it is very faint. The clear fluid should be kept in a stoppered bottle, and, should any carmine be precipitated, a drop or two of liquor ammoniæ should be added.

Formula for Boraæ Carmine.

Carmine	1 part.
Borax	4 parts.
Water	56 parts.
Alcohol	q. s.

Dissolve the borax in the water and add the carmine. Filter the solution, and add alcohol sufficient only to ensure free permeation of the tissue by the dye.

Thiersch's Formula.

Solution A.	Carmine	1 part.
	Liquor ammoniæ	1 „
	Distilled water	3 „
	dissolve and filter.	
Solution B.	Oxalic acid	1 part.
	Distilled water	22 parts.

Mix one part of A with 8 parts of B, and add 12 parts of absolute alcohol. Label "Thiersch's Carmine Reagent."

Modifications of Gerlach's original solution of carmine have been introduced also by Frey and others, but the three above given are all that are really requisite for staining nervous tissues.

The Staining Process.—Give the preference to Beale's solution, although its density from the glycerine renders the action slow. Dilute the strong solution with seven times its bulk of water, and filter. The sections should be placed in a comparatively *large quantity* of this dilute solution, covered with a bell-glass from dust, and allowed to undergo *very gradual* staining—a process which may occupy eight hours or longer. When a section removed on a slide exhibits sufficient staining, the reagent may be poured off, superfluous carmine removed by gentle washing, and all the sections immersed in a very dilute solution of glacial acetic acid (0·5 per cent.) for fifteen to twenty minutes. The acetic acid deprives the specimen of all diffuse staining and fixes the dye, more especially in the germinal centres, whilst at the same time the colour is brightened by its agency. Great care should be taken that neither section of staining solution is very alkaline in reaction, otherwise the staining will prove too deep and diffuse, and the structure itself injuriously affected. A minimum amount of ammonia, however, must be present in the dye, just recognisable by its odour; and if this be not the case, a drop or two of the liquor ammoniæ should be added prior to making the dilute solution. These sections may now be washed and mounted in glycerine or Farrant's Solution, or they may be dehydrated in the usual way by spirit, cleared up by oil of cloves, and mounted in Canada balsam or in dammar. With a few of these carmine-stained sections the student should try the following modified process of mounting, whereby valuable information is afforded. Several years ago I described in the 'Quarterly Journal of Microscopic Science,' vol. xvi., a method of displaying a great wealth of structure in the cortex cerebri by altering the refractive indices of the structural elements, and so producing very remarkable differentiation of structure. I there stated what follows:—"On placing an unstained section of cerebrum or cerebellum in the field of the microscope, saturated with spirit, little or no structure is

apparent, but, if a drop of essential oil be now allowed to run over it, there will be observed at a certain stage of the clearing up, and whilst the spirit is evaporating, a sudden starting out in bold relief of the cells, nerve-fibres, vessels, &c., which again disappear or partially fade on perfect clearing of the section. Now this appearance may be fixed by suddenly dropping over its surface a little balsam, and permanently mounting. Upon this fact depends the process now to be described. Sections treated with Beale's carmine solution (1 to 7 in strength), and washed with the acid wash, are placed, saturated with spirit, upon a slide. When the spirit has nearly all evaporated, a drop of oil of anise is allowed to flow *over* the section (not to float it up), and the clearing process is watched on the field of the microscope; then, just when the appearance referred to above is presented to view, a drop of balsam is allowed to run over the section, and a covering-glass permanently fixed on. In lieu of the oil of anise I frequently employed glycerine with the same results, and mount ultimately in glycerine jelly. . . . I will state my belief that this method will yet prove of most essential service in the estimation of the relative proportions of cell-processes in any individual section, and the most accurate tracing of any existing connections, for not by the deepest aniline staining have I yet succeeded in demonstrating the existence of so thick and numerous a series of processes diverging from the pyramidal layers of the cerebral cortex as by the method described above." These opinions have been confirmed, I am glad to see, by Prof. Stirling in his recent 'Text Book of Practical Histology.'[1]

Notes on the Value of the Dye.—Specially suitable for the large nerve-cells—their contents, their nuclei, and nucleoli. It exhibits well the connective cells and the vascular apparatus. It is less adapted for displaying the cell processes, and wholly fails to exhibit the details of structure in smaller nerve-cells such as those of the upper cortical layers. For the larger

[1] Dr. Stirling says:—"The processes of the cells (cerebrum) are best seen in preparations which are only *partially* cleared up under the influence of clove oil. This is a most important method of investigation. I have often seen in this way delicate fibrils, not unlike elastic fibres, and which are not distinct when the section is completely cleared up." ('Text Book of Pract. Histology,' p. 101.)

ganglionic cells and their immediate environment, nothing perhaps can surpass a successful carmine preparation, whilst it does not appear to produce any further shrinking of protoplasm or connective such as is produced by hæmatoxylin. It has been regarded, even by so eminent an authority as Charcot, as the only reliable dye for exhibiting the morbid conditions regarded as sclerosis of the different columns of the cord. This, however, is not the case, since aniline blue-black portrays the lesion even more distinctly. The more important objections attached to this dye are its variable results, the little definition usually given to the tissue elements from the tendency to diffuse staining; the unpleasant glare of the carmine tint for continuous work, and its unsuitability for examination by artificial light.

Picro-carmine Staining.

The Dye.—This valuable reagent is of special use in the preparation of nervous tissues, and cannot be dispensed with as it certainly ranks next to aniline black for such purposes. Ranvier's formula is as follows:—

Best Carmine	1 gramme.
Water	10 c.c.
Liquor ammoniæ	3 c.c.

Rub the carmine up with the water and add the solution of ammonia, aid the solution of the carmine by heat carefully applied. When dissolved and perfectly cold, add to it 200 c.c. of a saturated watery solution of picric acid. Place the solution in an open vessel, and with gentle warmth evaporate to one-third of its bulk. Filter and keep in a stoppered bottle, labelled "Ranvier's Picro-carminate Dye." Picro-carmine may be purchased in a solid form in a granular and imperfectly crystalline condition—a one per cent. solution is then used. I do not advocate its use, and from personal experience strongly advise the student to make his own reagent.

The Staining Process.—Immerse the sections in a small quantity of the picro-carminate solution for a period of from twenty to thirty minutes. Pour off the dye, draining off most of the superfluous fluid, and then *without washing the sections*

float them up by glycerine, in which they are to be mounted. It will be found advisable to stain each section upon the slide by dropping over it sufficient of the reagent to cover it wholly, and to clear it up with glycerine on the same slide it is to be mounted upon. The object served by this method is to preserve the double dye of picric acid and carmine, the former being very readily washed out by water. Upon the other hand washing freely, dehydrating with spirit, and mounting with balsam in the usual way, will usually yield us excellent carmine preparations, and, so far as my experience goes, better stained specimens than those subjected to the simple ammoniacal or borax solutions.

Notes on the Value of the Dye.—Its special value depends upon the presence of the two pigments, carmine and picric acid, and from the affinity displayed for either dye by different tissue elements, this reagent has acquired a well-deserved and favourable reputation. As a simple carmine dye used in the manner above described, it is also deservedly esteemed for the cerebral cortex, but for the combined staining with osmic acid or with aniline black it forms a most invaluable adjunct to our list of reagents. The merits and demerits of carmine staining pertain to the picro-carminate, but it is decidedly superior to simple carminate of ammonia and its *rôle* as a staining reagent more extensive. As a general dye for the nerve structures, it ranks next to aniline and aniline picro-carminate, and is far superior to logwood.

Aniline Staining.

The Blue-Black Dye.—This, which is by far the most valuable of the aniline series of dyes for the brain and spinal cord, is thus made :—

Aniline Blue-black	1 gramme.
Distilled water	400 c.c.

Dissolve, filter, and keep in a stoppered bottle labelled "Aniline black Dye, ·25% Aq. Sol." It may be convenient, however, to keep a stock solution of 1 per cent. strength, as occasionally a solution so strong may prove serviceable for rapid staining, and it may readily be diluted down to ·25 or

·5 per cent., where the usual dye is required filtering the solution prior to use. The solution as given above can be employed for staining fresh and hardened sections, the aqueous solution being the best dye we possess for the former. The alcoholic solution, as first recommended by Mr. Sankey, was the following :—

Aniline Blue-black	5 centigrammes.
Water	2 cubic centimetres.

Dissolve and pour it into 99 c.c. of Methylated Spirit.
Filter the solution and label "Alcoholic Solution of Aniline Black ·05 per cent."

Prof. Stirling recommends a solution double the strength of the above, thus :—

Aniline Blue-black	1 decigramme.
Water.	4 cubic centimetres.

Dissolve and add 100 c.c. of Rectified Spirit, and filter.
Label "Aniline Blue-black—Alcoholic Solution ·1 per cent."

Of the above dyes the student is recommended to keep always at hand an aqueous solution, ·25 per cent., and the alcoholic solution 0·1 per cent. I much prefer the aqueous solution for most purposes.

The Staining Process.—Sections of hardened cortex or pons, medulla, and spinal cord may be left in the aqueous solution (·25 per cent.) for one hour. In this time they will generally be found stained to a sufficient extent, when they must be removed to a vessel containing water, and well washed from superfluous dye. They are dehydrated by spirit, cleared up by oil of cloves, and mounted in balsam or dammar. *Sections of cerebellar cortex* should be deeply stained by aniline, gently washed by water, and then immersed for twenty to thirty minutes in a 2 per cent. solution of chloral hydrate. Next transfer to the following solution :—

Solution of Chloral Hydrate	2 per cent.
Oil of Cloves	equal parts.
Alcohol	q. s.

to dissolve perfectly and form a clear solution. Add the alcohol by degrees, stirring the solution with a glass rod and avoiding excess of spirit. During use carefully cover the watch-glass containing this solution, so as to avoid evaporation. The chloral removes diffuse staining, whilst the oil of

cloves clears up the section and enables us, by examining one occasionally under a low power, to decide when they have reached a satisfactory stage. When this has been attained, remove your section to a slide, rapidly wash with a little pure alcohol, thoroughly clear with clove oil, and mount in balsam. The alcoholic solution of aniline ·1 per cent. stains the sections of cerebrum, pons, and medulla in the course of a few minutes; they are then cleared and mounted in balsam in the usual way. Glycerine, being a powerful solvent of aniline, must not be made the medium for mounting these sections.

Notes on the Value of the Dye.—Its action is energetic, it is certain and constant in its results, readily controlled, so that any depth of staining may be obtained with ease. The tint given varies from a bluish-grey to a deep blue-black, and is a pleasant one for the eye, causing little or no fatigue. It enables us to obtain the clearest and sharpest definition of elements in a tissue without modifying their structure by shrinking or other change. No other staining agent displays the nerve-cell processes to such a remarkable extent as does this dye, the finest ramifications being followed out with ease. It has a very special affinity for protoplasm—staining the nuclei of the nerve-cells most deeply, then the nerve-cells and their protoplasmic extensions, and to a less intense degree the nuclei of the neuroglia and peri-vascular walls. The finely-formed nerve and connective meshwork forming the framework of the cortex is stained of a pale grey. This dye fails to produce any action upon the medullated sheath of nerve-fibres, affecting only the axis cylinder. Transverse sections, therefore, of nerve-fibres, such as are seen in cross sections of the medulla, cord, and nerve-trunks, exhibit the axis cylinder stained of a dark blue, the white matter of Schwann surrounding it; whilst the inter-tubular connective, likewise faintly stained, differentiates the medullated tubes from each other. For transverse sections, therefore, of nerve fasciculi in any region, this staining reagent will prove of the utmost service. Its value for connective tissue stuctures is very limited, its *rôle* being chiefly confined to nerve elements.

Osmic Acid Staining.—This method we owe to Professor Exner. It is peculiar in the fact that the hardening and stain-

ing proceed simultaneously, the same reagent being employed for both purposes. The preparation of the hardened brain by immersion in osmic acid has already been described, and we have now simply to detail his further treatment of the sections obtained on the microtome. These sections, owing to the deep staining they undergo, must be *extremely thin*, and should be placed in glycerine immediately, since prolonged immersion in alcohol injures them seriously. Transfer a section to a glass slide and add a few drops of strong liquor ammoniæ. Absorb all superfluous moisture by bibulous paper, and after a short time for the ammonia to affect the section thoroughly, drop the cover on without injury to the preparation, which has now become softened by the ammonia. It is at this early period that the section may be examined with greatest advantage. For permanent preparation Exner surrounds the cover-glass with the soluble silicate called "water-glass." Formerly he used to stain with ammoniacal solution of carmine, but, finding the results obtained were attributable solely to the ammonia, he has dispensed with carmine for this purpose.

Notes on the Value of this Method.—The medullated fibres can be traced upwards into the highest realms of the cortex, exhibiting a wealth of structure which no other method displays. The medullated sheath is deeply stained, and can be traced distinctly in the case of the minutest nerve fibres. The nerve-cells, although stained, do not form such prominent objects as by other methods of staining, this process being especially adapted for tracing the ultimate course of medullated fibres through the different layers of the cortex and determining their final destination. Exner states that the staining of the minute fibres occasionally disappears in time, and the student should also be aware that the brain structure swells up under the action of ammonia, so that the section is increased in size to one-third its full diameter.[1]

Double Staining and the Use of Compound Pigments.

Under this head I would include some of the most valuable methods we possess for delineating the minute structure of the

[1] For the results obtained by Exner with this process, see Abstract in 'BRAIN,' Part XV.

nervous system. Picro-carmine, as consisting of two pigments, would naturally fall under this category; but, since it is employed in the same way as the simple dyes, I have found it more convenient to include it amongst them. The methods of staining to which I now refer are those in which the tissue is first submitted to one dye, and the result subsequently modified by the addition of a second pigment. In these cases either different histological elements assume the tint of each pigment, or the former staining is greatly improved in character by the second pigment combining and modifying the tint acquired; in the former case a genuine double staining is obtained; in the latter, the union of two or more pigments gives but the effect of a single tint, yet one of very valuable quality.

Aniline Picro-carminate Staining.

Three pigments are here used, viz., the aqueous solution of aniline blue-black 0·25 per cent., and Ranvier's compound pigment—picro-carmine. Sections which should be very thin may be stained on a glass slide by dropping over them by a pipette sufficient picro-carmine to cover the section completely. When deeply stained by the reagent, the latter is drained off and the section covered in like manner by a quantity of the aniline blue-black solution. It will be found that the action of the aniline proceeds much more rapidly upon a section stained by picro-carmine; ten minutes usually suffice to produce the desired result. This result is acquired when upon draining off the dye the section is found to have changed from the bright carmine to a deep violet tint. Wash the section well in water, dehydrate by spirit, clear by clove oil, and mount in balsam. In this way the most beautiful effects are obtained, which are specially valuable and instructive. The tint is much less fatiguing to the eye than the bright glare of carmine, whilst in the differentiation of nervous structure in the hardened brain this method of staining stands unrivalled. The deeper the tint desired, the longer immersion in aniline is required; but for the more satisfactory and pleasing effects I have usually found it suffice to stain for half an hour in the picro-carmine and fifteen minutes in aniline solution.

Notes on the Value of the Dye.—This double staining enhances the value of an ordinary picro-carminate preparation in the fact that a better differentiation of structure is obtained, and examination by artificial light rendered as agreeable and valuable as by daylight. The neuroglia or connective element is deeply stained, and its nuclei are prominent objects; the grey matter of the brain is marked off from the central medulla by a much deeper staining of its elements. The nerve-cells are well shown, and their nuclei take the deepest tint. All bundles of medullated nerve fibres cut across by transverse section exhibit their central axis cylinder of a purplish colour, surrounded by the unstained medullated sheath, outside which is seen the intertubular connective and its nuclei stained of lighter hue than the axis cylinder. The vascular channels and their nuclear elements are stained in a satisfactory manner. This staining reagent is very suitable for exhibiting to low powers the coarse structure of the brain, and sections through a whole hemisphere treated by this method are most instructive for naked eye examination or the coarse objectives.

Picro-aniline Staining.

A useful staining of medulla and spinal cord may be obtained by employing Judson's "Cambridge Blue" as the first pigment, washing off superfluous dye, and then by momentary immersion in a saturated solution of picric acid the section acquires a brilliant green staining, which exhibits structural details remarkably well. Since both pigments are soluble in alcohol, the sections should be very rapidly dehydrated, cleared by oil of cloves, and mounted in the usual manner.

Osmic Acid and Picro-carmine.

The Staining Process.—The section is immersed in a solution of osmic acid 1 per cent., carefully covered over so as to confine this very volatile reagent, as far as possible, to the tissue to be acted upon. When the latter has acquired a dark brown tint it should be removed, well washed, and lightly stained with picro-carmine. Such sections must be mounted in glycerine or glycerine jelly. Sections of limited size, such as sections

through the hemispheres of the brain in small animals or the pons and medulla, may be conveniently acted upon by the osmic acid contained in a watch-glass covered with a small glass plate. This is a most valuable method of staining.

Hæmatoxylin with Aniline.

The Staining Process.—Sections are first stained with logwood according to directions already given, and immersed *for a few seconds only* in the aqueous solution of aniline blue-black 0·5 per cent. A solution of chloral hydrate, 2 per cent., will remove any excess of aniline staining. Next, well wash the section, *rapidly* dehydrate by alcohol and mount sec. art. This process is adapted chiefly for sections of cerebellum, and its special value will be referred to later on.

The above are all the methods of staining which I have found to be of especial value, but I append here two methods of double staining for the cortex of the cerebellum, advocated by Prof. Stirling,[1] and of the value of which I have not had personal experience.

Eosin and Logwood.

Stain a section for a few seconds in a very dilute watery solution of eosin (1 part to 1500 of water) until it has a faint red colour. Great care must be taken not to overstain. Wash with water, stain the section with logwood, and mount in dammar.

Picro-carmine and Iodine Green.

Stain a section in picro-carmine. Wash it in water acidulated with dilute acetic acid, and, after washing in pure water, stain again by means of iodine green and mount in dammar.

[1] 'Practical Histology,' p. 100.

(*To be continued.*)

Critical Digests and Notices of Books.

L'Hérédité Psychologique. Par TH. RIBOT. Paris, Germer, Baillière & Cie., 2me éd., 1882.

THIS "study," forming part of the Bibliothèque de Philosophie Contemporaine, professedly philosophical, is not very strictly scientific. It is, however, extremely interesting and well written, and replete with the results of extensive reading of the now somewhat numerous and distinguished investigators who have observed, speculated, and even experimented upon heredity and its allied subjects. Among them the writings of our own illustrious countrymen, Darwin and Herbert Spencer, are frequently quoted, and Mr. Galton's work upon "The Heredity of Genius" is by no means forgotten. The author remarks of Mr. Galton's book, that it has merits and defects sufficiently common in English works; containing as it does many figures and facts, and but few general ideas; and we may without injustice reciprocate the criticism by saying that M. Ribot's book is sufficiently marked by the opposite faults and merits of French writers, in that it contains a larger proportion of general ideas to the figures and facts which ought to support them, than is desirable in a work of scientific character.

Not that some foundation of facts is not supplied. Indeed, the first half of the volume professes to supply these alone; but they are thrown down somewhat in a heap, like a load of stones, not examined and analysed and sorted as specimens to see how much or how little they prove; which leads us to think that the method of this work may be greatly improved upon by future writers on this most interesting and important subject. Perhaps the question of heredity in man may not always remain more interesting than important in consequence of the difficulty of interfering, at least in civilised society, with the breeding of

men and women. Perhaps in the future a more general knowledge of the heredity of qualities may lead to better results by individual selection than was ever obtained by the will of a despot in Prussia in the selection of females for his grenadiers, or that of a proprietor in Kentucky in selecting males for his dark women.

The author has scarcely justified his choice of a title for his work as L'Hérédité Psychologique, seeing that it deals more fully with the more obvious and distinct facts of somatic than of psychologic heredity. No doubt psychological quality is based upon the hereditary substance, whatever that may be, and, although we may dispute Gall and Spurzheim's notions of intellectual and moral heredity as depending upon the inherited shape of the head, we can scarcely doubt the existence of a true principle underlying their doubtful detail, namely, the principle that moral and intellectual heredity depends upon the inheritance of a similar organism.

But the facts of moral and intellectual heredity, that is to say, those which it is the professed purpose of this volume to elucidate, are extremely difficult to appreciate with any degree of scientific accuracy. It is so easy to observe that some peculiarity of form or feature descends in a family; the thick lip of the Hapsburgs, for instance. But it is quite another thing in point of difficulty to trace the descent of mental qualities, or to account for variations, should the descent be unmistakably broken. Thus, a late Emperor, a man of mild temper and high courage, has been succeeded by a son in whom these qualities would seem to be reversed. Thus the audacious financier of Egypt has been succeeded by a son who is equally timid and honest. Such startling changes may be read by the fierce light which beats upon a throne; but how to account for them, that is the difficulty. M. Ribot would tell us to look to the maternal parents for an explanation; the sons, as a rule, inheriting their qualities from the mother, the daughters from the father. But is this so? A few examples certainly will not prove it, and it is just one of those questions which can only be answered by what M. Ribot describes as the defective method of Mr. Galton, that is to say, by facts and figures, and by using the figures in

strict relation to corresponding notions, a rule of statistical science which is by no means invariably observed. An important example to the contrary may be read in the work before us, where the author attempts to refute the late Mr. Buckle's objections to the doctrine of heredity as applied to mental qualities. Not to risk the probable errors of a retranslation, we give Buckle's words from the original:—

"We often hear of hereditary talents, hereditary vices, and hereditary virtues; but whoever will critically examine the evidence will find that we have no proof of their existence. The way in which they are commonly proved is in the highest degree illogical; the usual course being for writers to collect instances of some mental peculiarity found in a parent and in his child, and thus to infer that the peculiarity was bequeathed. By this mode of reasoning we might demonstrate any proposition; since in all large fields of inquiry there are a sufficient number of empirical coincidences to make a plausible case in favour of any view a man chooses to advocate. But this is not the way in which truth is discovered; and we ought to inquire, not only how many instances there are of hereditary talents, &c., but how many instances there are of such qualities not being hereditary. Until something of this sort is attempted, we can know nothing about the matter inductively; while, until physiology and chemistry are much more advanced, we can know nothing about it deductively. These considerations ought to prevent us from receiving statements which positively affirm the existence of hereditary madness and hereditary suicide; and the same remark applies to hereditary disease; and with still greater force does it apply to hereditary vices and hereditary virtues; inasmuch as ethical phenomena have not been registered as carefully as physiological ones, and therefore our conclusions respecting them are even more precarious."[1]

In answer to this indictment M. Ribot cites Maupertuis's observations upon the inhabitants of a town containing one hundred thousand inhabitants, not with respect to their virtues, vices, talents, or maladies, but as to the individuals among them who had been born with six fingers. None of the objections which Buckle raises to the logic of the usual arguments,

[1] "History of Civilisation in England," vol. i., pp. 160, 161.

as to the heredity of the shifting and indistinct mental qualities which he has designated, can in any way apply to the totally different quality of sexdigitism of which Maupertuis found an example hereditary through four generations, and reckoned that supposing that only five persons in the twenty thousand inhabitants had this physical peculiarity it was 800,000,000 to 1 that the peculiarity would not continue itself by accident through three consecutive generations. But sexdigitism is a quality which can be distinctly defined, virtue and vice are qualities which cannot be; sexdigitism is a rare peculiarity, virtue and vice are common to all men, and to meet Buckle's objections by such a reply is to leave them unanswered.

We can have no doubt now that Buckle was too sceptical as to the moral and intellectual progress of mankind through the operation of heredity in the transmission of the moral and intellectual ameliorations of civilisation; but surely he was right in insisting that scientific methods should be applied to a scientific inquiry, and that the *post hoc propter hoc* argument too often used in these inquiries should not be accepted with facile faith in its efficiency.

A most important illustration of the nature of Buckle's objections may be found in the facility with which heredity is commonly attributed as the cause of mental disease in which ascending relatives have been insane; for it has needed no more than evidence showing that a parent or grandparent has been insane to establish the hereditary character of almost any case of mental disease; the fact being ignored that the accidental causes which operated in the parent may equally operate *de novo* upon the child, and even that the insanity of the parent may cause the insanity of the child indirectly, but subjecting the child to moral and physical evils, such as grief or shame, or physical misery. If there were the same degree of probability that the child of an insane person would be insane from the influence of heredity as, according to Maupertuis, there is that the child of a man with six fingers will have six fingers, the civilised countries of the world would before this have been filled with madmen; unless, indeed, stern laws against the procreation of hereditary madmen were enacted. That no such laws have been, or are likely to be, made is a strong indication that here-

ditary influences have not that certain and constant effect which would justify such laws for the prevention of a dire and overmastering mischief. What we have to do is to find out the marks, if we can, by which hereditary insanity may be discriminated from accidental, and to find out the circumstances, if we can, which favour the transmission of the tendency to it. We are not quite ignorant even now in these matters, but the so-called laws of psychical heredity do not seem likely to lead us far in this intricate investigation as to the effects of inheritance, as distinct from the effects of all other influences, which may be called education, upon the moral and intellectual qualities of men and women.

These laws, according to M. Ribot, are:—

1*st.* That parents have a tendency to bequeath all their psychical characters, general and individual, ancient and newly acquired [law of heredity direct and immediate].

2*nd.* One of the parents may have a preponderating influence upon the mental constitution of the infant [law of preponderance in the transmission of characters].

3*rd.* The descendants often inherit the physical and mental qualities of their ancestors, and resemble them without resembling their parents [atavism].

4*th.* Certain physical and mental dispositions very clearly determined, manifest themselves in the descendants at the same age as in the ascendants [law of heredity at corresponding epochs].

Certainly we must accept as a law that like begets like—a law which was not discovered yesterday; for we have been told in a very old writing that "the fathers have eaten sour grapes and the teeth of the children are set on edge;" and the Roman poet reminds us that—

"Fortes creantur fortibus et bonis."

But the laws of exceptions above expressed in the feeble terms of the potential mood ought scarcely to be called laws until we have succeeded in discovering their positive conditions. We have the one great law of heredity which, from the philosophical point of view, the author considers a fragment of the more general law of the universe, that nothing which has been ceases

to be, and therefore that heredity is the law of life arising from the partial identity of the elements of the organism in the parents and the offspring. But the numerous exceptions to this law, the variations which put on the appearance of spontaneity, can we reduce them to any constant rules or formulas? We venture to think that, in spite of the vast importance of the task, we have not yet acquired scientific knowledge of these exceptions, that is to say, knowledge which will enable us to foretell when they will take place. Heredity is the strongest bond of determinism, yet it allows so much movement that it can never be predicted of the individual to what extent it will press his character into the old paternal mould, or leave it to be influenced by post-natal events. Its tyranny over the race is certainly greater than over the individual, but even in the race it is liable to large and as yet incalculable interference.

M. Ribot, in the eloquent passage which concludes his work, compares the man of nature with the man of civilisation, and remarking that the infinite distance which seems to separate the two extremes has certainly been traversed, he says, "Without doubt this evolution, the resultant of the complex play of numerous causes, is not entirely due to heredity; but we shall have badly succeeded in our task if the reader shall not now comprehend that heredity has largely contributed to it," a modest statement well within the confines of the truth.

JOHN CHARLES BUCKNILL.

The Formation of Vegetable Mould through the Action of Worms, with Observations on their Habits. By CHARLES DARWIN, LL.D., F.R.S. London, Murray, 1881.

THIS work, affording new evidence of the great results attainable by the patient and long-continued observation of small matters, the exposition, as it were, by an eyewitness of a geological formation, gives us the pleasure of again meeting with Mr. Darwin in a department of science which does not often receive patient and cautious observation, namely, in that of psychology, and in a phase of animated nature where a less original observer would scarcely have dis-

covered a fruitful field of psychological inquiry. It is with the mind of the earth-worm, and not with the manner in which it incrusts our fields with a fruitful surface, that Mr. Darwin most interests us in these charming pages. But mind can only be evolved upon the foundation of sense impressions, and worms are blind and deaf and have but a feeble sense of smell. "The nervous system is fairly well developed, and the two almost confluent cerebral ganglia are situated very near the anterior end of the body." To say that worms are blind is perhaps not strictly accurate, for although they have no organs of vision, a strong and continued light causes them to retreat into their burrows, unless such light is shed upon them when they are employed in dragging leaves into their burrows, or in eating them, or whilst they are paired sexually. "When a worm is suddenly illuminated and he darts like a rabbit into his burrow, we are at first led to look at the action as a reflex one, but the different effects which a light produces on different occasions, and especially the fact that a worm, when in any way employed, and in the intervals of such employment, is often regardless of light, are opposed to the view of the sudden withdrawal being simply a reflex action," and is, the author thinks, attributable to attention and to some mental power.

The fact that light is capable of stimulating the cerebral ganglia of the earth-worm through the tissues which cover them, without the intervention of any sense organ, is a fact now resting upon unquestionable authority, which we would fain commend to the notice of the distinguished American physician who has recently published his observations on the transmission of the stimulus of light to the human brain through the skin and bone of the forehead. There is, however, some difference between the diaphanous skin of a worm and the dense and opaque skin and bone of a man's forehead, and there is also some difference between the credibility of Mr. Darwin and that of some other observers.

The sense of touch, including the perception of vibrations, is keen in worms. They do not hear the loudest sounds, but if the pot in which they have been kept for observation be placed upon a pianoforte they withdraw into their burrows

immediately a note is touched. Facts are adduced which show that they possess some sense of smell; and as they appear to like cabbage leaves as food, and to distinguish between different varieties, and as they choose various other substances for food, it is likely that they possess the sense of taste. But it is in the sense of touch that they live and move and have their being, and it is by this they exercise that degree of choice in the selection of materials for lining their burrows, which has enabled the illustrious author to write so much at length upon their habits as displaying intelligence. He may well have been surprised to find that a creature so low in the scale of animal life was able to select and to use the materials of its subterraneous architecture according to the strictest fitness of shape, form and substance. Pursuing his investigations in this matter, the author summarises what he has observed of the mental qualities of his lowly subject thus:—

"*Mental Qualities.*—There is little to be said on this head. We have seen that worms are timid. Their sexual passion is strong enough to overcome, for a time, their dread of light. They perhaps have a trace of social feeling, for they are not disturbed by crawling over each other's bodies, and they sometimes lie in contact. According to Hoffmeister, they pass the winter either singly or rolled up with others in a ball at the bottom of their burrows. Although worms are so remarkably deficient in the several sense organs, this does not necessarily preclude intelligence, as we know from such cases as those of Laura Bridgeman; and we have seen that when their attention is engaged they neglect impressions to which they would otherwise have attended, and attention indicates the presence of a mind of some kind. They are also much more easily excited at certain times than at others. They perform a few actions instinctively, that is, all the individuals, including the young, perform such actions in nearly the same fashion. This is shown by the manner in which the species Pericheta eject their castings, so as to construct towers; also by the manner in which the burrows of the common earthworm are smoothly lined with fine earth, and often with little stones, and the mouth of their burrows with leaves. One of their strongest instincts is the plugging up of the mouths of

their burrows with various objects; and very young worms act in this manner. But some degree of intelligence appears to be exhibited in this work—a result which has surprised me more than anything else in regard to worms" (p. 35).

Why worms plug up the entrances of their burrows, and why they line them with leaves and other substances, the author has not been able to decide. Perhaps to conceal their burrows from scolopenders, their bitterest enemies, perhaps to keep water out, or cold air, as they dislike cold, and the lining also may be for the sake of warmth; but "whatever the motive may be, it appears that worms much dislike leaving the mouths of their burrows open."

But whatever the motive, either for plugging the orifice or for lining the tube, it can scarcely be disputed that the manner in which it is done displays a degree of intelligence surprising in so lowly an animal.

"If a man had to plug up a small cylindrical hole with such objects as leaves, petioles or twigs, he would drag or push them in by their pointed ends, but if these objects were very thin relatively to the size of the hole, he would probably insert some by their thicker or broader ends. The guide in his case would be intelligence. It seemed, therefore, worth while to observe carefully how worms dragged leaves into their burrows; whether by their tips or bases or middle parts. It seemed more especially desirable to do this in the case of plants not natives to our country; for, although the habit of dragging leaves into their burrows is undoubtedly instinctive with worms, yet instinct would not tell them how to act in the case of leaves about which their progenitors knew nothing. If, moreover, worms acted invariably through instinct or an unvarying inherited impulse, they would draw all kinds of leaves into their burrows in the same manner. If they have no such definite instinct, we might expect that chance would determine whether the tip, base or middle was seized. If both alternatives were excluded, intelligence alone is left; unless the worm in each case tries many different methods, and follows that alone which proves possible or most easy; but to act in this manner and to try different methods makes a near approach to intelligence."

A fairer statement of a proposition could scarcely be made, nor can it be thought that its caution is overstrained, although, no doubt, another great biologist is right in saying that Darwin may be reckoned upon to state any proposition most strongly against himself. The answer to the proposition was carefully worked out with leaves of various shapes and textures, single leaves, double leaves with their points cut off, or tied together with silk, or cemented together, and above all with triangles of writing paper, and the conclusion arrived at, that worms do display intelligence in their manner of plugging up their burrows, is shown to be inevitable by the very careful and most interesting details to be found in the work. The questioning experiments were so put that chance and instinct were eliminated, and nothing left to account for the behaviour of these low animals but intelligence, much to the surprise of the questioner, for "many higher animals have no such capacity," ants, for instance; but then an ant has not such a perfect measuring wand as a worm possesses in its sensitive equiform body, and, not forgetting their antennæ, no such means of acquiring a notion of the shape and dimension of things. And it is to be remarked that the most intelligent of the brutes, as the monkey, the elephant and the parrot, are especially gifted with some organ which enables them to ascertain the shape and dimensions of bodies, indicating that the rudiments of intelligence are best obtained through the medium of tactile impressions. As to what touch may be when it is the sole sense, Mr. Darwin says, "it may be well to remember how perfect the sense of touch becomes in a man when born blind and deaf as are worms. If worms have the power of acquiring some notion, however rude, of the shape of an object and of their burrows, as seems to be the case, they deserve to be called intelligent; for they then act in nearly the same manner as would a man under similar circumstances." Mr. Darwin thinks that it will strike every one as improbable that worms should possess intelligence; "but," says he, "it may be doubted whether we know enough about the nervous system of the lower animals to justify our natural distrust of such a conclusion. With respect to the small size of the cerebral ganglia [of worms] we should remember what a

mass of inherited knowledge, with some power of adapting means to an end, is crowded into the minute brain of a worker ant."

JOHN CHARLES BUCKNILL.

Studien über das Bewusstsein. Von Dr. S. STRICKER. Wien, 1879.

Studien über die Sprachvorstellungen. Von Dr. S. STRICKER. Wien, 1880.

Studien über die Bewegungsvorstellungen. Von Dr. S. STRICKER. Wien, 1882.

THE pamphlets, the titles of which are placed at the head of this article, contain, as might be expected from the eminence of their author, a valuable discussion of various philosophical and psychological problems. Taking these pamphlets in the order of their publication, the first deals with the phenomena of consciousness. Prof. Stricker sets out, like other philosophers, with an analysis of human knowledge. He shows that the knowledge which can be presented in the consciousness of any person at one time is only a small part of the whole, much the greater portion being latent. The portion of knowledge which can be simultaneously presented in consciousness he proposes to call *actual* or *living*, and the remaining portion *virtual* or *potential*, following in this respect the well-known division of force or energy in physical science. This distinction is not of much importance, and we pass on to his second division of knowledge, which is of much greater significance.

Knowledge may be divided into that which is direct or immediate, and that which is indirect or mediate. The highest degree of certainty must always be found in immediate knowledge, and Prof. Stricker accepts, without reservation or criticism, the *cogito, ergo sum* of Descartes as our ultimate grounds of certainty and the starting-point of philosophy. But even if the right of the implied *Ego* to be regarded as a direct deliverance of consciousness be allowed to pass unchallenged, we may be permitted to ask the author how he

would vindicate the right of the expressed *ergo* to be included in a statement of *immediate* knowledge.

The relation of the brain to consciousness is next dwelt upon, and two hypotheses explanatory of the connection are stated. According to the one, an independent entity—the soul—dwells in the brain, and plays upon its material substance as a musician plays upon his instrument; while the other, briefly stated, asserts that consciousness is a function of matter. But surely dualism and materialism are not the only hypotheses which have been advanced to explain the connection between the brain, or, more generally stated, matter, and mind. Idealism, for instance, asserts that the matter of the brain, like every other external existence, is a product of mind, while Realism (Indifferentism of Mansel, Monoism of Haeckel, and Pantheism of theologians) assumes that mind and matter are but two faces of one substance which underlies both. But the truth is that Prof. Stricker passes by as unfruitful, as Locke did before him, the discussion of the relation subsisting between mind and matter, and satisfies himself with offering a compromise. He thinks that both dualists and materialists may agree to say that nerve cells are endowed with psychical functions. The dualist, while using this expression, may think that the soul makes use of the nerve cell to form the conception, and the materialist that the process in the cell begets the conception. Personally we have no great objection to this solution, but we prefer to say that mental phenomena are the *correlatives* of certain material changes in the structure of the brain, and *vice versa*. This statement is a mere summing up of facts which can be readily proved, and which are, indeed, admitted by all, and no assumption whatever is involved in it.

Prof. Stricker points out that nerve fibres, as well as nerve cells, are endowed with psychical functions, and very justly remarks that, were it otherwise, the feeling correlated to the function of each cell in the same brain would be as distinct and independent as the consciousness of two individuals. He does not, however, hazard a conjecture as to the nature of the function of the fibre. Mr. Herbert Spencer's theory of the respective functions of cells and fibres is by far the most rational we have seen. He maintains that the activities of the

cells are the correlatives of feelings, and those of the fibres the correlatives of the relations between feelings. And if thinking is the establishment of relations between simple and compound feelings, it will be seen that the structural counterpart of abstract thinking must chiefly consist in the formation of new connections between nerve cells.

Prof. Stricker now proceeds to discuss the origin of our ideas, observation and memory, common emotional or subjective sensations (Gefühle) and special intellectual or objective sensations (Empfindungen), organic sensations, eccentric projection of sensation, Weber's or Fechner's law, the theory of general and abstract names, original and acquired ideas, and various other interesting problems. These subjects are handled with great ability, and even those who are intimately acquainted with philosophical speculations will find in the author's exposition much to interest and instruct them.

Prof. Stricker then deals with the problems of sleep, dreams, illusions, hallucinations, and delusions. It appears to me that he would have been more successful in his explanations of these conditions had he extended his survey to somnambulism, ecstasy and allied conditions, epilepsy, and especially epileptic auræ, migraine regarded as a sensory epilepsy, delirium, and mania. A modification of Dr. Hughlings-Jackson's theory of epilepsy, which may be briefly termed the theory of cerebral cortical discharge, would suffice to explain all those conditions, and the very fact of ranging them alongside one another would represent them in a more familiar light to the mind, and render them less extraordinary if not less incomprehensible.

The author next discusses the theory of a cheerful, gloomy, or irritable disposition, and the nature of the *will*, along with some of the philosophical problems which cluster around it; but we must now pass on to consider briefly the contents of the second and third pamphlets. These tracts are occupied with the consideration of the mental representations which are associated with speech (Sprachvorstellungen) and those associated with voluntary movements (Bewegungsvorstellungen). The word *Vorstellung* is very difficult to translate into our language. It means literally a *placing* of something *before*

the mind, and consequently includes presented as well as represented feelings. The subject-matter of the last two tracts, therefore, embraces the feelings which accompany speech (articulatory movements, vocalisations, and gestures), and other voluntary movements; whether the movements be rendered into actualities (presented feelings), or only revived in thought (represented feelings). But we shall do no violence to the meaning of the author if we briefly term the subject-matter of these two tracts as a consideration of the *feelings* associated with speech and movements. But as speech, whether it be spoken, written, or acted, when it is objectively considered, depends like bodily movement upon muscular contractions, the feelings which accompany the two processes must to that extent be the same, and consequently only one fundamental theory comes under our consideration at present, as indeed the author admits. It is impossible for me to enter into the details of Prof. Stricker's theory, and I must refer those who are interested in these questions to the original papers. Prof. Stricker's theory is, although worked out with great power and originality, practically the same as that of Prof. Bain, which has been common property with English thinkers for a quarter of a century; and allowing for such minor differences as are sure to arise in the mental products of original thinkers working independently of each other, I would not wish for a better epitome of the thesis of Prof. Stricker in 1880 than the words used by Prof. Bain in 1868. "In very lively recollection," says Prof. Bain, "we find a tendency to repeat the actual movements. Thus, in mentally recalling a verbal train, we seem to repeat the very words; the recollection consists of a suppressed articulation. A mere addition to the force or vehemence of the idea, would make us speak out what we speak inwardly. Now, the tendency of the idea of an action to become active shows that the idea is already the fact in a weaker form. But if so it must be performing the same nervous rounds, or occupying the same circles of the brain in both states."[1] It is a matter for regret that Prof. Stricker did not know, or at least does not mention, the cases of amnesic aphasia recorded by Broadbent and Wernicke. The case

[1] 'Mental and Moral Science,' by Prof. Bain; 2nd ed., 1880, p. 90.

described by Broadbent is an example of "word blindness" and the lesion was found in the angular and adjoining gyri (part of visual centre), while Wernicke's case is an instance of "word deafness," and the lesion was found in the temporo-sphenoidal convolutions (auditory centre). He also does not refer to the important fact discovered by Brissaud and Charcot that in old cases of ataxic aphasia a streak of secondary degeneration is to be found in the knee of the internal capsule and in the crusta. In a case of dysarthria under my own care, not yet published, in which the fibres of the knee of the internal capsule were found softened, I traced a streak of degeneration through the crusta, pons, into the anterior pyramid and median raphé of the medulla oblongata. The case of anarthria and masticatory paralysis recorded by Dr. Barlow, in which there was softening of the posterior part of the third frontal convolutions in both hemispheres, and the cases recorded by Magnus, Lépine, Oulmont, Kirchoff, and myself, in which anarthria and the other symptoms of bulbar paralysis were caused by disease of the lenticular nuclei (with probable injury of the knee of the internal capsule) are full of significance to the theory which Prof. Stricker maintains, that the motor centre for speech is also the motor centre for articulation and vocalisation (Lautebildung). Prof. Stricker says that the ruling doctrine of the origin of our mental representations of movements in the external world asserts that the visual impressions produced by the different phases of a moving body blend together to form a mental representation of the movement of this body. If this be true with regard to the ruling doctrine in Germany, it is certainly not true with reference to this country for the last quarter of a century. "The sensations of sight," says Prof. Bain, "are partly *optical*, the effect of light on the retina, and partly *muscular*, from the action of the six muscles."[1] He then states that the optical sensations are light, colour and lustre, and the sensations involving the muscular movements of the eye are visible movement, visible form, apparent size, distance, volume and situation. This simple statement from Prof. Bain is indeed an admirable abstract of Prof. Stricker's thesis, and

[1] 'Mental and Moral Science,' by Prof. Bain, p. 60.

consequently it is not necessary for me to give a detailed analysis of a theory which is so well known to British Psychologists. Prof. Stricker has made some interesting observations with an instrument—the well-known toy sold under the name of the Wheel of Life or Zoetrope—which he designates the Stroboscope. He believes that the illusion of motion in this toy is not due entirely to the persistence of visual impressions, but that it is mainly caused by the intermittent attempts of the eye to retain the rotating images within the field of vision. This is a modification of the muscular slip theory advanced by R. Addams, and more recently by Dr. Emile Juval, to account for the class of optical illusions first noticed by Brewster, and named by him "illusions of subjective complementary motion." The whole of this subject has been so ably handled by Dr. Sylvanus P. Thompson, in a paper "On Optical Illusions of Motion" which appeared in a recent number of 'BRAIN,' that it is unnecessary for me to make any further remarks on the subject. Prof. Stricker brings his discussion of these all-important questions to a close by a consideration of Cause and Effect, the universality of judgment *a priori*, God and Force, and various other problems which are full of enduring interest. His theory of causation is, as might be expected, closely allied to that of Prof. Bain, and is indeed essentially the same as that of M. de Biran, "who," according to Cousin, "placed the type of causality, of the will and of liberty in the phenomenon of muscular effort."[1] But this theory seems to me to have been disproved in advance by the philosophy of Kant; it has certainly been roughly handled by the followers of Kant in this country—Sir W. Hamilton and Mr. Herbert Spencer. With regard to Spencer it may, indeed, be said that the Empirical has as much right to claim his adhesion as the Intuitional school. One of the greatest advances of recent times in philosophical speculation was made by Mr. Spencer when he pointed out what Prof. Max Müller calls the pre-historic genesis of the congenital capacities which are the sources of our intuitive knowledge,

[1] 'History of Modern Philosophy,' by M. Victor Cousin. Translated by O. W. Wright, 1852; vol. ii., p. 346.

and thus effected a reconciliation between the Empirical and Intuitional schools. And I may be permitted to express the opinion that Prof. Stricker would find in this reconciliation the key to the solution of many of the philosophical problems which appear at present to be so obscure and perplexing to him.

JAMES ROSS.

The Physiology of the Nervous System in its relation to Psychic Facts. By Dr. MARIO PANIZZA.

WE learn from the preface that this work contains a critical examination of two postulates of the physiology of the nervous system, viz.—(1) That the nerves are conductors of the sensory impressions from the periphery to the nervous centres, and of the motor impulses of the will from the nervous centres to the muscles; and (2) That external objects, to be perceived, must first make an impression on the sense organs.

The author proceeds to make what seems the startling announcement that neither of these postulates has any foundation in experience, and that they are both entirely contrary to the truth. Physiologists are, no doubt, familiar with this controversy, from a study of the writings particularly of the late Mr. Lewes; but Brown-Séquard, Ferrier and others have discussed it from time to time, and from all points of view. Nowhere, however, probably, have the doctrines in question been attacked with more vigour, or by anyone who has brought to bear on the discussion more physiological knowledge than the present author, or a wider range of reading among philosophical as well as physiological writers. His first point is to attempt to show that science has obtained the idea of the double transmission of sensory impressions and motor impulses of the will, from the speculative ideas of the ancients, and has consequently only subordinated the facts observed to these ideas. The cause of the adoption of the theory, according to this view, was the ancient opinion that the soul occupied a fixed position in the centre of the organism; and this in turn was due to the notion that the soul was an unextended principle. As the soul was at the centre, impressions of sense must, of course, be conveyed to it, and, equally of course, motor

impulses must be conveyed from it. That this view was held by the ancients is proved from the writings of Democritus, Plato, Aristotle, Galen, &c.

The author next shows that anatomy is opposed to the view of double transmission, since (1) The nerves neither converge to a central point in the brain, nor do they diverge from such a point; and (2) Neither do they run isolated and autonomous from one end to the other. Various and differing opinions of different anatomists on these points are detailed, and it is shown that, according to the theory, the spinal cord ought, for instance, to be much more voluminous at its upper than its lower end, whereas, in fact, the more voluminous part is below; and in some animals, as the *Crotalus torridus*, the section of the lower part is eleven times greater than of the upper. The views of modern writers, as Vieq d'Azyr, Cuvier, Bell, Rolando, Gall, are vigorously attacked. As regards the isolated and autonomous course of the nerves, Haller's statement is quoted to show how the theory warped his observation:—"Every nervous filament," he says, "from its commencement to its termination is thus distinct, in order that the sensation of each filament may reach the brain, free from the sensations of every other filament." Henle, &c., wrote to the same effect. When observers, as Roudanowski, in 1865, showed anastomoses taking place between the nerve-fibres, it was assumed that the observations were erroneous; and when later observers again pointed it out, the condition was assumed to be one of very great rarity, and the very researches of anatomists, conducted by teasing the nerve-fibres with needle-points, were so arranged as to destroy the anastomoses. The necessities of the theory compelled observers to overlook the significance of ganglia, and specially of the nervous network found in many places in the body.

As regards the physiology of this question, it is shown that anatomical arrangements and physiological theories were assumed and framed in order to comprise the already accepted theory. With respect to Sir Charles Bell's discovery, our author thinks his merit consisted in having suggested a new process of experiment which he was the first to apply, not to objective researches, but to prove a particular opinion of his

own, viz. that the various functions of nerves, and, therefore, the function of transmission of sensory and motor impulses, had different fibres. His theory, according to our author, presupposed four propositions:—(1) That the seat of the sentient principle and of the will is in the brain. (2) The notion of double transmission. (3) The anatomical disposition imagined by the ancients to adapt the nervous system to this mechanism; and (4) The existence of distinct routes for the transmission of the sensory impressions and of the excitements to voluntary contractions. In fact, Bell's experiments, according to Dr. Panizza, had chiefly the effect of turning the attention of physiologists completely in another direction, viz., to the question, what were the directions taken in the roots and in the spinal marrow by the two opposite currents.

On the other hand, experiments which showed that section of the posterior nerve-roots did not quite abolish sensibility were overlooked; and particularly Arnold's experiments (on which, by the way, Mr. Lewes laid so much stress). This author divided the posterior nerve-roots, and then removed the skin so as to destroy the peripheral apparatus of tactile sensibility, and yet found that the animals perfectly executed movements depending on the perfection of muscular sensibility. Again Marshall Hall and others found they could obtain muscular movements by irritating the posterior nerve-roots.

The author then examines the theories framed to account for these results, contradictory of expectation; but cannot accept any of them as well founded. "Diffusion of the stimulus," "recurrent movement," &c., he sets on one side as unsatisfactory.

In an interesting section on the true signification of reflex movements, Dr. Panizza shows that the ordinary theory takes no account, either of the influence of ganglia, which may act as centres of reflection, or of the inosculations of nerves, which actually occur in plexuses and even in the course of nerve-fibres. The author distinctly maintains, however, the necessity for transmission in the case of voluntary movements, as distinguished from reflex.

The question of paralyses of sensation and motion consequent on division of nerves is then considered, and it is main-

tained that the usual explanation presupposes the theory of double transmission, and that some of the effects of division of nerves are quite opposed to the theory, as for example, when division of a nerve is not followed by loss of sensibility in the part supplied (as sometimes occurs).

The writer spends some time in attempting to establish the thesis, that excitability is a universal property of the nervous system. This he does by showing, that the gradual progress of discovery has resulted in the knowledge that parts formerly believed inexcitable have been shown to be so. Thus the optic thalami, the occipital lobes, and even the frontal lobes have, one by one, been found excitable so as to produce movements. The remarks made on this point are very interesting, and worthy of longer notice, but space forbids.

The law according to which the action of stimuli is propagated in the nervous network is, according to Marshall Hall and the author, this: From whatever point the irritation starts, the effects may be diffused by the nerve-fibres in all directions; and a corollary from this law is the position that a stimulus applied to any point whatever of the nervous system, may determine in various districts of the organism, and in all directions, the most varied disturbances of sensation and of voluntary motion.

The various hypotheses of physiologists to reconcile facts observed, with the acceptance of the theory, are then considered, and all are rejected, the author contending that the large (or, as he terms it, *infinite*) series of hypotheses required is itself an evidence of its incredibility. Even the acceptance of the theory of cerebral localisations seems to him to be upset by those by no means rare cases recorded in pathology, in which pathological destruction of the centres was not accompanied by loss of the movements supposed to be dependent on them.

The second part of the book, dealing with the physiology of sensation, is even more interesting than the former, but must be more shortly dealt with. The author proceeds on the same plan by showing how the notion originated with the ancient writers regarding the unextended character of the sentient principle. The whole question of presentation and

representation is discussed, and the question of vision is considered in all its bearings.

The author's conclusions are—

1. That the postulate of impressions has no foundation in experience.

2. That science, starting from this postulate, has at once been compelled to introduce into the explanation of the facts unextended principles.

3. That the explanation obtained thus, by means of hypotheses, into which unextended principles enter, requires, in the arrangement of the facts, many other hypotheses which are in contradiction to experience.

4. That science solves these difficulties only by entirely abandoning the extended, and betaking herself entirely to unextended principles.

5. That knowledge, built upon such a foundation alone, does not correspond with that which we have of objects, which was the point from which the inquiry set out, the fact whose explanation was sought. We may, therefore, conclude that that postulate is not at all conformable with the truth, and, like that of double transmission, must be absolutely dropped by a positive teaching.

Dr. Panizza's work is highly original, and we should be glad to see it translated. A. RABAGLIATI.

The Brain of the Cat (Felis domestica). Preliminary Account of the Gross Anatomy. By BUTT G. WILDER, M.D., Professor of Comparative Anatomy in Cornell University, U.S., &c. Read before the American Philosophical Society, July 15th, 1881.

THIS is a contribution towards the supply of a want which the author considers as an opprobrium to anatomy, viz., the exact and detailed description of the brain in typical examples of various mammiferous animals. It is more limited in its aim than the memoirs of Meynert, Krueg and others; but with the object in view of describing certain forms of brain which could be most easily procured, Professor Wilder made choice of the

brain of the cat, not only on account of the readiness with which specimens may be obtained, but also because of its being less subject to variations from differences of race than that of the dog or some others of the carnivora. The memoir is illustrated by four plates, containing in all twenty figures, the most of which are twice the natural size, and have been drawn with great care from a considerable number of specimens, so as to present a fair view of the average forms.

The description is not systematic, but rather in the form of an explanation of the figures; nevertheless it is of such a nature as to bring out all the main features of external cerebral anatomy which they are intended to illustrate. Some new names have been invented for a certain number of the parts; while in regard to the greater number an attempt has been made, by slight changes, to adapt the received names to the author's views of a reformed system of anatomical nomenclature. There is, as is well known to most writers and teachers in anatomy, some risk in this attempt, and Prof. Wilder, in riding his hobby, has not entirely escaped from a tinge of pedantry which is apt to infuse itself into the straining after perfection in scientific nomenclature. But with this exception, on which, if we were disposed to be critical, we might have made further remarks, the account of the coarser anatomy of the cat's brain, which is given in this memoir, must be looked upon as a valuable contribution to the exact and detailed description of an important organ in a particular tribe of animals.

As Professor Wilder's memoir does not attempt more than a simple description and nomenclature of the parts, and does not enter into any comparison of the brain of the cat with that of other animals, or profess any general views, there is no ground for further remark in this notice. But we shall look with interest for the continuation of Professor Wilder's work in the minuter anatomy of the brain in the same animal; and we may hope on some future occasion to go more fully into an examination of that and other works on the comparative anatomy of this organ.

In conclusion, we would remark that there is very little doubt that the scientific knowledge of the structure of the central nervous organs is, in the first instance, mainly to be

advanced by the multiplication of carefully executed descriptions of individual forms similar to that which has now been under our notice, so as to furnish ample materials for their future comparison, and the consequent foundation of that more complete knowledge of cerebral structure which may prove a secure guide in the illustration of its physiological and pathological conditions. ALLEN THOMSON.

Lehrbuch der Krankheiten der peripheren Nerven und des Sympaticus. Von Dr. ADOLPH SEELIGMUELLER. 398 pp. Brunswick, F. Wreden, 1882.

THIS treatise on the diseases of the peripheral nerves and the sympathetic is one of a series of short medical text-books. In a second volume, the author intends to describe the diseases of the brain and cord in a similar style. Dr. Seeligmüller is known as an excellent practical observer, not wanting, however, in a thorough theoretical basis, and therefore it was to be expected that he would write a practical and useful book. The progress of neuropathology has been so rapid that works of ten years' standing have become nearly antiquated, and so the busy practitioner will be glad to find in Dr. Seeligmüller's book a short, but exhaustive and thoroughly scientific account of the present state of knowledge concerning the diseases of the nervous system.

The book is divided into a general and a special part. In the former the author gives an introduction to the study of nervous diseases, and describes the different methods of examining the functions of the nerves (sensibility, mobility, reflex-action); then he speaks of the causes of nervous affections in general; the main subject, however, of this general part is a chapter on the therapeutics of nervous diseases in general. This is subdivided in three parts: physical, chemical, and surgical remedies.

As physical remedies he describes, in the first place, the methods of applying cold and warm water; then follows a very good account of the use of electricity, illustrated by numerous diagrams of electric apparatus, the motor points, &c.

This is followed by a short account of the methods of massage and Swedish gymnastics.

The second division of this therapeutical chapter includes a description of the different drugs used in the treatment of nervous affections. We may mention here that the author has had good results by the use of Cannabis indica in doses of 0·2–0·5 gramme, as a hypnotic. For neuralgic pains he recommends Gelseminum and Butylchloral (croton chloral).

In the second part of his book Dr. Seeligmüller treats of the diseases of the peripheral nerves; neuralgia in its various forms, paralysis and spasmodic affections of peripheral nerves, and the anatomical diseases of the latter, neuritis, atrophy and neoplasms, injuries.

In the chapter on the diseases of the sympathetic, the author is well aware that some of these affections, such as Graves's disease, hemiatrophia facialis, cannot be considered as real diseases of the sympathetic nerve, but may have their origin in other nervous centres; for practical purposes, however, it is convenient to classify them with some other, more or less obscure, affections of the vaso-motor, trophic and secretory nerves, such as: sclerodermia, local asphyxia of the extremities, hydrops articulorum intermittens, &c.

Dr. Seeligmüller's book is an extremely useful, and valuable addition to the literature of neuropathology, and I have no doubt that an English translation of it would meet with great approval among medical practitioners. R. H. Pierson.

General Physiology of Muscles and Nerves. By Prof. Rosenthal (Erlangen). London, Kegan Paul, 1881. 8°. pp. 324.

Physiologie des Muscles et des Nerfs. By Prof. Ch. Richet (Paris). Germer Baillière, 1882. 8°. pp. 924.

Though these works have the same title, their scope is widely different. Prof. Rosenthal's volume (one of the "International Series") is intended to give a semi-popular account of the whole subject; a difficult task, but which could not be entrusted to more competent hands. Electro-physiology is fully treated, in fact occupies one-half of the volume. The

author accepts Du Bois-Reymond's hypotheses, and gives a masterly résumé of the whole question from this point of view. The English translation, though readable enough, contains a large number of peculiar expressions, literally translated from the German instead of converted into the received technical terms. Thus, why speak of muscle "pulsations" instead of "contractions"? Or again of "inductive currents," of "chains" (i.e. batteries), of "ganglion-balls," &c. At page 176 the following curious sentence occurs: "A wire of this sort applied to a conductor traversed by currents is called a *diverting arch* (i.e. a deriving circuit); the ends of the wire with which it touches the body to be examined are called the *feet of the arch;* and the distance between these feet is called the *distance of tension.*"

Prof. Richet's stately volume consists of twenty-four lectures, chiefly devoted to the phenomena of nerve and muscle irritability. The electrical phenomena of animal tissues, and still more those of electrotonus, are treated less systematically than might have been expected. The author has studied the phenomena of muscular contraction on the cray-fish; and his results are both interesting and important. Many phenomena are clearly displayed in the lower forms of organisation, which in the higher are far more difficult to single out from the more complex manifestations of their functions. The comparative method in experimental physiology will, no doubt, throw great light upon the nature of the fundamental facts of muscular and nervous action.

The first twelve lectures discuss the alterations of muscular irritability under certain conditions, the phenomena of contraction and cadaveric rigidity, &c., concluding with some subjects of special interest to the physician: muscular sense, atrophy, "tendon-reflexes." We are rather astonished at the author's attributing the latter to a sensory stimulation of the tendon itself. Most of our readers will, however, find still more interest in the perusal of the second part of the work, relating to the nervous system. After discussing nervous irritability and vibration, the author devotes four lectures to the illustration of reflex action, its laws, modifications and manifestations. The great practical importance of a thorough

knowledge of reflex actions becomes daily more evident. They are the means of testing the condition of nerves and nerve centres; and upon them are based many of our most potent therapeutical measures. To them we are impelled to look for the explanation of some of the highest psychical functions of the human organism. Will itself, Prof. Richet believes, is reducible to reflex action, but is it impossible to believe to spontaneous discharges of energy in certain directions fixed by the original constitution and subsequent education of nerve centres? At any rate, however tempting the hypothesis which reduces all actions to reactions, our knowledge concerning nerve-cells, their nutrition and functions, is scarcely ripe enough to justify generalisation on such a scale. Full of interest are the lectures on the conditions of cerebral life, and on the cerebral irritability and reactions. A strong argument in favour of the direct excitability of the cerebral cells is the fact of their latency being longer than that of nerve fibres, and the longer duration of the effects of single stimulation. They are also much more readily exhausted.

The last lecture sums up the author's views on irritability in a comparison between this property as manifested by muscles, nerves and nerve centres.

The book is illustrated with many myographical tracings. Notwithstanding its somewhat bulky appearance, it is sure to be welcomed by all who wish to rest their study of morbid nervous action upon a solid physiological basis.

A Clinical Treatise on the Diseases of the Nervous System. By Prof. M. ROSENTHAL, of Vienna. Translated by L. Putzel, M.D. New York and London, Sampson Low & Co. 2 vols. 8°. pp. 530.

THE term "clinical" must be understood in its German significance. The chief characteristics of the book lie rather in the stress placed on pathological anatomy. With reference to treatment, the English reader will find in it valuable hints with reference to hydropathic measures, a subject far too much neglected here.

Epilepsy and other Chronic Convulsive Diseases. By W. R. Gowers, M.D., F.R.C.P. Churchill. 8°. pp. 308.

This work, based on the Gulstonian lectures delivered by the author in 1880 (see 'Brain,' Vol. II. p. 262), is a conscientious monograph on epilepsy in the light of the most modern facts and theories, and based upon an extensive and well-digested personal experience. The chapter on treatment is well timed, as there is too much tendency now-a-days towards ignoring all drugs but the bromides, and failing these to give up cases as not susceptible of amelioration.

The Diagnosis of the Diseases of the Spinal Cord. By W. R. Gowers, M.D. 2nd ed. Churchill, 1881. pp. 86.

We owe a debt of gratitude to Dr. Gowers for having supplied a great want in medical literature. Within a small compass he has condensed, in a clear and accurate manner, all the important factors of spinal diagnosis. He treats successively of the medical anatomy of the cord, of its physiology in relation to the symptoms of its diseases, of the indications of position and of nature of disease. Histories of typical cases and a number of well-chosen diagrams serve to illustrate the principles laid down. The author's reading and clinical experience are equally extensive, and no better guide to the subject could be found. We hope every practitioner will avail himself of the advantages offered to him in this introduction to the study of spinal diseases.

On Chorea. By Octavius Sturges, M.D., F.R.C.P. Smith and Elder, 1881. Small 8°. pp. 200.

We agree with the author in thinking that the view generally taken of chorea in England is biassed by the exaggerated importance given to rheumatism in its pathogeny. The co-existence of the two diseases is far from being the rule. The heart itself may partake of the chorea movements; hence the cardiac disturbances observed. The fact that fright and

other psychical states are often the existing causes of chorea, and that girls are more subject to it than boys, show that it is rather a "functional" than an organic disease. It has certain points in common with hysteria. The resemblance between choreic jactitation and the purposeless movements of infants makes it appear as if the disease consisted in a temporary suspension of the educational acquisitions in the motor sphere. Dr. Sturges' book is most readable, good in style, and strong in argumentation.

Le Sommeil et l'Insomnie. By A. MARVAUD, M.D. Paris, and London, Sampson Low & Co., 1881. 8°. pp. 140.

THIS little book, which has gained to its author one of the prizes of the "Académie de Médecine," is a useful digest of what is known of the physiology and pathology of sleep. The first part treats of the phenomena of normal sleep; the second, of insomnia, occurring either by itself or as a concomitant of other morbid conditions. The work concludes with a full discussion of the treatment appropriate to the various cases.

Compendium der Electrotherapie. By Dr. PIERSON (Dresden). Third edition. 12°. pp. 200.

Guide Pratique d'Electrothérapie. By Dr. ONIMUS (Paris). Second edition. 12°. 320 pp.

DR. PIERSON'S is an excellent résumé of the whole subject of electro-diagnosis and electro-therapeutics. The physical principles, which after all are the most important to have grasped for a successful medical application of electricity, are accurately stated. Electro-diagnosis (which is of purely German growth, if we except the fundamental discovery of Marshall Hall) and the methods of treatment are described with sufficient clearness to be of practical use to the reader.

Dr. Onimus's little book is a *résumé* of the author's teaching, based upon his own physiological experiments and clinical experience. The writer holds curious views, opposed to every physical principle, about "the high tension and low chemical action"

of currents. He also holds the *direction* of currents of supreme importance in therapeutical applications. We believe that the relative positions of the poles on the body is a matter of almost absolute indifference. The chapter on treatment is much enlarged; its dogmatic tone will make it undoubtedly acceptable to those who have to use the galvanic current without any previous knowledge of batteries and their manipulation.

A. DE WATTEVILLE.

Clinical Cases.

A FURTHER CONTRIBUTION ON THE COURSE OF THE OPTIC NERVE FIBRES IN THE BRAIN.

BY J. DRESCHFELD, M.D., M.R.C.P.

Professor of Pathology, Victoria University, and Assistant Physician, Royal Infirmary, Manchester.

In the last number of 'BRAIN,'[1] I recorded two cases bearing on the above subject. I beg leave to describe now the history and post-mortem account of another case, which again strongly supports the theory of a semi-decussation of the optic nerve-fibres, and presents also some other interesting neuro-pathological features.

Th. P., æt. 52, married, a plumber by trade, was admitted into the Manchester Infirmary on May 26th, 1881, suffering from hemiplegia, hemianæsthesia, and hemianopsia, all on the left side, and died at the Convalescent Hospital, Cheadle, on November 4th, 1881.

The following is a brief outline of the case as taken by Dr. R. Maguire, then clinical clerk:—

The *family history* is good. Patient does not know of any of his relatives suffering from gout or consumption; he has had five children, one of whom died when young from croup.

Previous history.—Has never had syphilis; his habits have been regular. When a boy had an attack of typhoid fever. He has always enjoyed good health, though much exposed to wet and cold, till four years ago, when he suffered from an attack of gout, since then he has often been troubled with bronchitis and asthma; during last winter he had an attack of lead colic. Twelve months ago he noticed that he had to get up often at night to pass urine, he had no pain in the head, no vomiting, no pains in his loins, or dropsy of any kind. About a month before admission he noticed his eyesight failing; the left eye being the worse; vision then became suddenly worse, so that he was almost blind, and could hardly

[1] Vol. IV. p. 543.

follow his employment. In a few days more he became suddenly paralysed on the left side, without any pain or loss of consciousness.

Condition on admission.—Patient is a spare man, fairly healthy in appearance. There is a little œdema of the eyelids, of both legs, and of the left arm; arcus senilis is well marked.

The patient is much depressed in spirits, and very emotional, but his intelligence is good; he, however, complains of slight loss of memory; he does not complain of any headache or vertigo; there is no aphasia.

There is slight left facial paralysis, affecting the lower facial muscles only. There is almost complete paralysis of left arm and leg; the leg is extended, the foot turned inwards; there are no traces of any contracture, and the arm and hand rest in any position in which they are placed.

The deep reflexes (patellar and ankle-clonus) are absent both from the right and left side.

The superficial reflexes (plantar, cremasteric, abdominal, epigastric and scapular) are absent on the left side, but normal on the right side.

There is complete anæsthesia of the whole of the left side, extending exactly to the middle line of the body. The patient feels tactile impressions very imperfectly, both in the trunk and the extremities of the left side; there is also analgesia of the left side, and when pricked with a pin in the arm the patient feels a peculiar sensation running up the arm towards the neck; if pricked in the leg a similar sensation runs up the thigh. The sense for temperature is likewise diminished on the left side.

The sense of taste and of smell is normal. Hearing is diminished on both sides, but more on the left than on the right. The vision is bad, and there is complete left hemianopsia; different colours are perceived on the right side in their physiological order, on the left there is complete absence of colour vision. Ophthalmoscopic examination of the eye shows swelling of the disc, numerous hæmorrhages, and white patches in the retina, chiefly round the papilla, but not round the yellow spot. The retinal arteries are scarcely visible, the veins over the papilla large and tortuous. The pupils are slightly dilated, but react, though somewhat sluggishly, to light.

There is no paralysis of any of the oculo-motor muscles.

The muscular sense is not affected on the left side. The muscles on the left side feel flabby, but there is no marked atrophy.

The electric contractility, to the galvanic and the faradic current, of the muscles on the left side is diminished.

There is no blue line on the gums. The tongue is large and moist, teeth marked and coated with a thick black fur. Appetite is good, there is no vomiting. Bowels confined. Defæcation perfectly under control. The liver dulness and splenic dulness normal.

The voice is rather hoarse, there is a slight cough, with scanty, frothy expectoration of muco-purulent character. There is no dulness over the region of the lungs. A few moist rhonchi are occasionally heard.

Pulse eighty, full and incompressible. The arteries are rigid and tortuous. The heart's apex beat is visible in sixth intercostal space, and is outside the nipple. Heart's dulness increased both in the vertical and transverse diameter. The heart sounds are loud, the first somewhat clangy. The first sound is reduplicated over the ensiform cartilage, the second over the pulmonary cartilage.

Micturition profuse, sometimes involuntary. Urine s. gr. 1009, pale, acid; contains a small quantity of albumen; no sugar. Microscopically, a few granular casts.

Diagnosis.—The case was looked upon as one of chronic Bright's disease, in which cerebral hæmorrhage had taken place, implicating the left thalamus opticus and left internal capsule. The retinal changes, the marked cardiac hypertrophy, the slight amount of albumen, the low s. g. of the urine, and the small amount of œdema and absence of ascites made us look upon the case as one of granular kidney, or chronic interstitial nephritis, which view was also strongly supported by the etiological element in the case (the patient was a plumber by trade) and the history of an attack of gout. The dimness of vision which the patient complained of previous to his apoplectic attack was no doubt due to the albuminuric retinitis. The hemiplegia, hemianæsthesia and hemianopsia were best accounted for by assuming one apoplectic focus situated in the above-given locality. The primary renal disease, the sudden onset, the absence of headaches, vomiting, &c., all pointed in favour of hæmorrhage rather than a tumour.

Progress.—The patient's condition remained unaltered for some time. Experiments were tried with an electro-magnet, but without causing diminution of the anæsthesia; a solenoid was also applied around the left lower extremity for some hours daily, with no better results.

On July 1st, 1881, the patient developed an attack of gout in the left great toe; and there was also diagnosed slight pleuritic effusion on the left side. Some of the fluid was withdrawn from the pleura by a subcutaneous injection syringe, and when treated after Garrod's method to show crystals of uric acid, gave positive results.

During the next few months the patient's condition underwent but little change.

The hemiplegia slightly improved, especially as regards the leg; the patellar reflex, which was noticed as absent before, became slightly marked on the left side, but not on the right. There was no tendency to contraction.

The anæsthesia remained unaltered.

The hemianopsia also remained unchanged.

The optic neuritis and retinitis gradually underwent the degenerative changes, and numerous white patches were visible, whilst the swelling of the disc receded.

The albuminuria remained the same; occasionally the urine contained a small amount of blood.

The œdema of the legs and eyelids disappeared, the gouty toe assumed its natural appearance, and the pleuritic effusion diminished somewhat, though not entirely. In this condition the patient was sent, on September 10th, to Cheadle, where he remained in very much the same condition up to November 4th, when he had another attack of cerebral hæmorrhage, became comatose, and died the same day.

A *post-mortem* was made by Mr. A. H. Young, pathologist to the infirmary, on November 5th.

On opening the skull it was seen that the left cerebral hemisphere felt firmer than the right, but was not otherwise altered. The brain was removed, and on section the interior of the right hemisphere was found to be the seat of a very extensive hæmorrhage, which had considerably damaged and ploughed up the basal ganglia and distended the ventricle, but left the cortex perfectly intact. It was impossible, even after hardening of the brain, to make out the seat of the original lesion; the optic tract and the geniculate bodies, however, were found to be perfectly healthy and quite away from the hæmorrhage. The medulla and cord were taken out and examined microscopically, after having been sufficiently hardened, and no changes whatever were found; there was neither descending degeneration of the lateral columns nor any changes in the posterior columns, either in the dorsal or lumbar region.

The heart showed marked hypertrophy of the left ventricle; the kidneys were small, red and granular, and showed changes affecting chiefly the capsules of the glomerule and the interstitial tissue. (The kidney changes in this case, and in some other cases of Bright's disease from chronic lead poisoning, have some important bearings on the pathology of Bright's disease, and will be the subject of a separate publication elsewhere.)

Remarks.—While the above reported case, owing to the

very extensive second attack of hæmorrhage to which the patient succumbed, does not allow us to exactly localise the exact situation of the lesion which produced the hemianopsia, it yet forms another valuable support for the theory of the semi-decussation of the optic nerves in the optic tract. It shows further that the hemianopsia was not due to pressure or disease on the tract or the corp. genicul., for these parts were found perfectly normal and quite away from the seat of hæmorrhage.

Another interesting feature in the case is the absence of tendon reflexes on both sides (on the left they were slightly marked during the last few months of life) and the absence of any tendency to contracture in the paralysed limb. The spinal cord showed absence of any descending changes. But no changes similar to those described by Westphal (in one case of general paralysis of the insane with absence of tendon reflexes) and situated in the inner side of the post. horn could be made out in this case.

GLIOMA OF THE RIGHT OPTIC THALAMUS AND CORPORA QUADRIGEMINA.

BY DAVID FERRIER, M.D., F.R.S., &c.

Physician to the National Hospital for the Paralysed and Epileptic.

THE following case seems worthy of record, as illustrating the exceedingly complex symptomatology of tumours affecting the *tegmentum* and its ganglia.

Samuel H., æt. 14, was admitted into the National Hospital for the Paralysed and Epileptic on May 13, 1881.

Previous History.—The commencement of the present illness was thought to be a fall on the ice four years ago. Some kind of fit occurred the day after, but there were no other symptoms till September 1880. In this month he had a fit. In October he had a series of fits, with general convulsions and retraction of the head, lasting for about five hours. Next day he had frequent vomiting. In November he had two fits of a similar character. It was observed that after these fits the right eye was turned inwards, and continued so more or less for six weeks. At this time there was diplopia. Several fits occurred, and occasional sickness subsequently, but he was apparently improving and getting stronger, till a month before admission, when it was observed that he began to reel in his gait, and to use the left leg with difficulty. There seemed to be a tendency to reel specially towards the left side. This difficulty in walking had gone on increasing, so that he had not been able to walk alone for a fortnight.

The left arm was also observed to be affected, being unsteady and weak, so that the patient could not use his left hand to button his clothes or hold a fork.

The patient had occasional attacks of headache, and also pain and numbness in the left arm.

State on admission.—Exceedingly dull and heavy-looking, but responds intelligently to questions as to name, age, &c. Says he has pain in the back of the head on pressure or percussion.

Motility.—The ocular movements upwards and downwards are normal, but the lateral sweep is restricted, especially towards the left and a nystagmus tends to occur.

The power of converging the eyes is entirely lost, so that he cannot look at the tip of his nose or at an object brought close up to the eyes. Nor do the pupils show any contraction at the attempts at accommodation. The movements of the face, tongue and jaws are apparently unaffected. The arms retain all their movements, but the left is distinctly weaker than the right. Grasp of right hand = 45 lbs., of left = 15 lbs.

The left hand also oscillates when he attempts to touch or lay hold of anything. Otherwise it remains still and free from all tremors or twitching.

The legs can be moved freely in all directions when he is lying in bed, though the left is distinctly feebler than the right. In attempting to walk he lifts the left foot high off the ground, and throws it forward in a brusque and ataxic manner. Cannot walk without support.

The patellar reactions are very distinct, the left excessive and almost tetanic. Ankle-clonus is readily induced in the left. The plantar, abdominal and epigastric reflexes are obtained on both sides, but better on the right side. The cremasteric reflex was obtained equally on both sides.

Sensibility.—Tactile sensibility is somewhat defective on the whole of the left side, but painful impressions are felt and correctly localised.

Sight is good. He can read 3 Nettleship with the right eye, and 4 Nettleship with the left.

The pupils are equal and react to light, but there is no alteration on attempts at accommodation. Ophthalmoscopic examination reveals well-marked double optic neuritis.

Hearing is better on the right than left side. Hears a watch at 18 in. on left, at 3 feet on right.

Taste and smell good, and no appreciable difference on the two sides.

The subsequent history may be summed up shortly as increasing torpor and mental hebetude, greater weakness, amounting towards the end to complete paralysis of the left arm and leg, and partial of the face, with anæsthesia and analgesia. Fits occurred at intervals, varying somewhat in character, but all tonic rather than clonic.

In one, in which he was carefully observed by the attendant, both arms were rigidly flexed, the legs flexed at the knees, the face drawn to the right, the head retracted, and both eyes widely opened and turned upwards. The spasms lasted about a minute, and were followed by unconsciousness for several hours.

In another attack the arms were rigidly extended, the hands clenched, the head retracted, and the legs extended.

In other attacks, again, there was loss of consciousness with-

out muscular rigidity. In one of these, seen by Dr. Beevor, he lay with the body turned to the left. The face was dusky and covered with perspiration. The right pupil was somewhat larger than left, and insensible to light, while the left reacted slightly. Slight external strabismus existed in the right eye. The breathing was slow, and the pulse sixty per minute. At the end of ten minutes he opened the eyes and moved the right limbs a little. Well-marked ankle-clonus and knee-jerk existed in the right. Plantar reflex was obtained on the right side slightly, but none on the left.

Death occurred on July 27th, 1881.

Post-Mortem Examination.

The skull cap was thin. The dura mater was not adherent, but tense. The convolutions were somewhat flattened and dry, the veins being large and distended. The right parietal region felt firmer than the rest of the brain.

The cranial nerves were intact.

The posterior extremity of the right optic thalamus projected behind the crus cerebri and was in contact with the middle peduncle of the cerebellum,—as seen from the base.

On division of the corpus callosum and exposure of the lateral ventricles and corpora quadrigemina, the right optic thalamus and right side of the corpora quadrigemina appeared, while retaining their normal shape and surface, larger than the left.

The greatest antero-posterior diameter of the right thalamus was 2 inches, while that of the left was 1½ inch. The greatest width of the right was 2 inches, but of the left only ¾ inch.

The right anterior tubercle of the corpora quadrigemina was about ¼ inch larger in all its diameters than the left. The consistence of the enlarged parts was softer than the normal structure, and, on section, the surface presented the characteristic appearances of a glioma shading imperceptibly into the surrounding tissue. The internal capsule and ganglionic structure of the right thalamus and lenticular nucleus were indistinguishable, and the sub-thalamic region and tegmentum of the crus cerebri seemed involved in the growth. The foot of the crus cerebri and locus niger were distinct. The nucleus caudatus, internal capsule and anterior part of the lenticular nucleus were of normal appearance. The enlarged optic thalamus pressed backward against the anterior or quadrangular lobe of the right side of the cerebellum, and was closely appressed and moulded against this and the middle peduncle. This portion of the cerebellum, instead of having the laminæ running parallel to each other, forward and outwards, had an

irregularly convoluted appearance, as if thrown into folds by compression into a smaller space. The pressure on the anterior surface of the right lateral lobe caused the inferior semilunar lobe to be closely applied against the medulla oblongata. The right lateral lobe of the cerebellum was thus somewhat distorted, and the antero-posterior diameter shortened by about half-an-inch as compared with the left.

Remarks.—The diagnosis made in this case, viz., a tumour affecting the right side of the cerebellum and pons, was only approximately correct, nor does it seem possible, even with the actual condition before us, to infer otherwise than vaguely as to the symptoms which should have existed during life.

The fact of the existence of an intra-cranial tumour was indicated by the general symptoms, viz., headache, vomiting, optic neuritis and convulsions; and the reeling gait and tonic or tetanic nature of the convulsive attacks were symptoms which, as has been pointed out by Hughlings-Jackson, are characteristic of tumours of the cerebellum. That the cerebellum was affected here is very clearly shown by the compression and distortion of the right lobe by the backward growth of the tumour; but whether in this, or in the cases where the tumour is actually in the cerebellum itself, the tonic spasms are in reality cerebellar, or, as I am more inclined to regard them, due to irritation of the corpora quadrigemina, is a point not to be decided by clinical facts alone. But the facts of experimental irritation of the cerebellum and of the corpora quadrigemina, which I have elsewhere described, would lead me to regard the affection of the corpora quadrigemina as the essential factor. In this case the corpora quadrigemina were directly implicated by the invasion of the morbid growth, and several of the symptoms seen in this case have been found in connection with tumours in this neighbourhood. Disorders of locomotion, and certain forms of ophthalmoplegia have been specially noted. In this case there was total paralysis of the convergence of the eyes, and weakness of the lateral movements, the others being unaffected. But there was no paralysis of reflex irido-motor action, and there was scarcely any appreciable difference in the power of vision in the two eyes. The right was a trifle more acute than the left. The locomotor incoordination was very marked, not merely disorder of equilibration, but a curious ataxic action of the legs. Cases of impaired co-ordination of locomotion with ophthalmoplegia in connection with indications pointing to disease in this region have important physiological bearings. The partial hemiplegia of motion and sensation on the left side, which might have been the result of a tumour of the right half of the cerebellum pressing on the subjacent

sensory and motor tracts, was no doubt, in this case, due to the direct implication of the right internal capsule which was involved in the growth. The oscillations of the left hand on volitional movements may be regarded also as due to the same cause, in accordance with the observations of Charcot in reference to the lesion in post-hemiplegic choreic disorders.

Abstracts of British and Foreign Journals.

Schultze on recovery from Tabes. (*Archiv f. Psych.* xii. p. 232).—Erb in his article on Tabes dorsalis (*Ziemssen's Encycl.* vol. xiii. p. 598, American edition) writes:—"But even where the disease is fully developed, we may, although very rarely, see recovery take place, or an improvement bordering on recovery. I am in possession of two cases which demonstrate this. In the one, there were lancinating pains, unsteadiness, weariness, and distinct ataxy of the legs, paræsthesiæ in the domain of the ulnar nerve, and vesical weakness. After the malady had lasted for several years, the patient recovered completely with the exception of slight vesical weakness; and for the past few years he has attended to his duties as a civil functionary without suffering any inconvenience."

This same patient came under Dr. Schultze's observation in June 1880, and the only symptoms of spinal disease that he presented were absence of the patellar reflex and a degree of paralysis of the bladder, with vesical catarrh. The gait was normal, and there were no disorders of sensibility. The patient died suddenly of corrosive poisoning, twelve years after the appearance of the initial symptoms, and eight years after the disappearance of the more prominent symptoms of tabes. *Post mortem*, there was found diffuse degeneration of the posterior columns in the lumbar region; degeneration of the outermost parts of Burdach's columns in the dorsal region (least marked in the lowest fourth of the dorsal portion of the cord); partial degeneration of Burdach's columns, especially of their outer portions, and slight affection of the columns of Goll in the cervical region.

This case shows that though most of the symptoms of tabes may disappear, the pathological appearances characteristic of the disease may still be present. It also lends support to the view that, even in the early stages of tabes, important organic changes are to be found, and proportionally discredits the theory of a purely symptomatic stage of the disease prior to the stage of organic change.

From a clinical standpoint there is no doubt that this case may

very fairly be looked upon as a case of tabes with almost complete recovery. And it may be argued that from an anatomical standpoint the absence of granule-cells, which generally appear in the earlier stages of atrophic processes, justifies the same conclusion; in other words, that we have to deal with simply the remains of an old degeneration, and not with an actually progressing degeneration. It must be remembered, however, that the absence of granule-cells is not a very reliable test in this matter, for, if the atrophy of nerve fibres develops slowly, granule-cells may not be found.

Schultze calls attention to several interesting features in this case: (1) Though there was lesion of the outer parts of the columns of Burdach in almost every part of the cord, there was not persistent ataxia. Schultze does not regard it as proved that degeneration of Burdach's columns causes ataxia, and he thinks that the results of this case, and also the fact that where there is extensive degeneration of the posterior columns the ataxia may spontaneously disappear, show that other inhibitory or reinforcing influences are operative in the production of ataxia besides the lesion which forms the spinal substratum. (2) The case teaches us that a moderate degree of degeneration in the posterior columns of the lumbar enlargement need not cause permanent anæsthesia or paræsthesiæ. (3) There was general atrophy of the cord, with diminution in the number of the nerve fibres. This atrophy, which is not usual in cases of tabes, was observed chiefly in the dorsal and lumbar parts of the cord, and was not confined to the posterior columns, but was also found in the lateral columns, and in the anterior cornua of the lumbar enlargement.

Wolff on a case of Tabes.—Wolff (*Archiv f. Psych.* Bd. xii. p. 44) reports a case of tabes with unusual clinical and pathological complications. The patient was a woman, aged 57. Her illness commenced with smarting pains in the lower extremities, and in a few weeks tremors of the upper extremities were observed when voluntary movements were made. Subsequently, ataxia of the lower limbs, paræsthesiæ, loss of the patellar reflex, occasional tension of the muscles of the limbs, incontinence of the urine and fæces, and decubitus, developed, and the patient died after an illness of 14 years. The occurrence of tremors of the upper extremities, along with the symptoms of tabes, rendered the diagnosis difficult. The case might have been a disseminated cerebro-spinal sclerosis in which the posterior columns were specially affected, or a multiple sclerosis with fascicular degeneration of the posterior columns,

or a sclerosis en plaques of the cord alone, with special complication of the posterior columns, or with fascicular degeneration of these columns.

At the necropsy there was found fascicular degeneration of the posterior columns, and in addition two foci of degeneration. The larger focus was immediately below the cervical enlargement, and implicated the anterior columns and portions of the lateral columns and anterior cornua. The smaller focus was at the level of the third cervical nerve, and affected the lateral columns only. There was thus a combination of tabes dorsalis, with the simplest form of a disseminated sclerosis of the cord. Whether the disease, in this case, is to be regarded as primarily interstitial (a primary meningitis) or parenchymatous, Wolff is unable to decide. Many facts point in favour of the former view; e.g. the universal thickening of the pia mater of the cord, the marginal degeneration found in the medulla oblongata and in various parts of the posterior columns, and the thickening of the ependyma in the upper part of the medulla oblongata, where no degeneration was visible. On the other hand, there was no local indication of a spinal meningitis, such as pain along the vertebral column, rigidity, &c. Wolff suggests that the disease of the posterior columns may have been parenchymatous, while that of the two foci was of a meningomyelitic nature.

The tremor of the upper extremities Wolff attributes to the patch of degeneration immediately below the cervical enlargement.

Schulz and Schultze on Acute Ascending Paralysis.—In Landry's paralysis, or as it is better termed acute ascending paralysis, the electrical excitability of the paralysed nerves and muscles is normal. There are cases, though, which present the general character of acute ascending paralysis but differ from it in exhibiting a rapid diminution of the electrical excitability. In this respect they resemble Duchenne's paralysis (poliomyelitis anterior subacuta); but they are distinguished from it again by the peculiar upward march of the paralysis, and by the fact that disturbances of respiration and bulbar symptoms are regularly present.

An example of this intermediate type is recorded by Schulz and Schultze (see *Archiv f. Psych.* Bd. xii. p. 457) as occurring in a man with a syphilitic history. After a lengthened prodromal stage the disease rapidly developed, and terminated fatally in four weeks. Diminution of electrical excitability and the reaction of

degeneration were only observed towards the end of the illness. There were also slight paræsthesiæ and transitory vesical weakness.

The post-mortem showed acute myelitis of the anterior cornua of the lateral columns (especially of the pyramidal tracts), and in some places, and to a less extent, of the anterior columns. The morbid appearances were found through the entire length of the spinal cord, and in the lower part of the medulla oblongata. Though the evidences of disease were most marked in the localities named, the whole cord showed signs of a degree of inflammation.

It will be seen that this case presents a further point of difference from the typical acute ascending paralysis in possessing such marked pathological features, for in the typical Landry's paralysis the pathological appearances are *nil*. The authors suggest that the acute ascending paralysis may perhaps represent the lightest form of a general spinal and bulbar inflammation, in which the lateral columns and the medulla are specially affected. In some cases the inflammation might be so slight that it would be very difficult of detection even by the best observers; in other cases there would be more decided evidences of inflammation. For example, in Eisenlohr's case of acute ascending paralysis, there were minute hæmorrhagic extravasations and small collections of white blood corpuscles and leucocytes in the medulla, and to a less extent in the cord. The authors mention a case that came under their own observation, in which, shortly before death, the facial nerve became paralysed, and its electrical excitability diminished; and in which the autopsy revealed meningitis and acute myelitis with swelling of the axis-cylinders through the whole length of the spinal chord, particularly in the lateral columns of the cervical and dorsal divisions of the chord. We may mention here another case of the authors' which shows by what gradations we may pass from Landry's to Duchenne's paralysis. Clinically the symptoms were those of Duchenne's paralysis, except that there were symptoms of disordered respiration, and the extent of the paralysis did not declare itself in the first few days. Pathologically there was a very intense poliomyelitis anterior, and a slight affection of the lateral columns, characterised by swelling of the axis-cylinders—the very opposite of the conditions found in the first mentioned case, where the myelitis of the lateral columns was the prominent lesion, the poliomyelitis the less important lesion.

The authors observe that it will aid us in the diagnosis of these cases if we recollect what the first-mentioned case proves, that we

may have an acute poliomyelitis with myelitis of the lateral columns without spastic symptoms.

Senator on Bulbar Paralysis.—Hemianæsthesia alternans has hitherto been regarded as a symptom pathognomonic of lesions of the pons. Recently, however, Senator has reported a case (see *Archiv f. Psych.* Bd. xi. p. 713) which shows that this symptom may be present though the lesion is confined to the medulla oblongata.

A man, aged 56, without losing consciousness was seized with an attack of vertigo. He had the greatest difficulty in swallowing, had a tendency to fall to the left side, had a feeling of cold in the left half of his face, and had an affection of speech which gave one the impression that he was suffering from some obstruction in the pharynx or larynx. There were no symptoms of motor paralysis, except that the tongue was protruded a little to the left, and the left eye appeared somewhat smaller than the right. The temperature was normal, but the pulse beat 120 per minute. Five days later he was seen by Senator. He was then complaining of difficulty in swallowing, of hunger, and of want of breath. Sensibility was almost completely lost in the left half of the face, and in the whole right half of the body, as well as in the right arm and leg. Attempts to swallow either liquids or solids caused hawking and choking, and the substance was returned, sometimes through the nostrils. The voice, once powerful and clear, had become a whisper, and there was still the inclination to fall to the left. The patellar tendon reflex was absent on both sides.

For a week there was little change in his condition. Examination with the laryngoscope showed partial paralysis of the vocal cords. The electro-cutaneous sensibility was either lost or very much diminished in the left face and in the right half of the body. The patient died of putrid bronchitis and broncho-pneumonia, after an illness of fourteen days in all.

The *post-mortem* revealed a small focus of softening in the outer portion of the left half of the medulla oblongata, and thrombosis of the left vertebral and posterior inferior cerebellar arteries. The greatest length of the focus was about 1 cm.; superiorly, it did not extend so far as the pons; inferiorly, it did not reach the level of the plane drawn through the calamus scriptorius. The greatest breadth of the focus was attained a little below the middle of the olivary body; here the restiform body and the contiguous portions of Burdach's column and of the lateral column, the ascending root of the fifth nerve, the motor nucleus of the vagus and a portion of

the fibre of the vagus, were all implicated. The olivary body, the root of the hypoglossus, and the nuclei of the hypoglossus and vagus were quite intact.

Senator remarks that the difficulty in swallowing, the snuffling speech (due to paralysis of the pharyngeal muscles), the altered voice, the rapid pulse, the hunger and the feeling of want of breath were all symptoms indicative in this case of lesion of the vagus nerve. The absence of vaso-motor disturbances (with the exception of a slight and transient lividity of the right arm), of polyuria and glycosuria, is worthy of note; as also the fact that there was no marked defect in the knowledge of the position and lie of the right extremities, notwithstanding the loss of ordinary sensibility in them.

Bernhardt on Athetosis. — The author (*Archiv f. Psych.* Bd. xii. p. 495) reports a case in which there were successively hemiplegia, hemichorea and athetosis. The observation is of special interest, in the first place as showing that hemichorea and other abnormal involuntary movements may develop as post-hemiplegic conditions, and in the second place as confirming Bernhardt's theory, that athetosis is merely a modified chorea.

The patient was a woman, aged 20. The nature of her first illness is unknown, but it commenced with swelling of the feet, and an affection of the speech which grew gradually worse; and in the course of a few weeks there was complete right hemiplegia and aphasia. Seven months after the commencement of her illness she was seen by Dr. Bernhardt, who observed that the right leg was dragged in walking; that the right hand and arm and upper arm were in continual, restless, rapid motion (chorea post-hemiplegica); that there was right hemianopsia; and that there was aphasia, the patient being unable to name objects or to select those named, or to repeat the names after any one.

Iodide of potassium was administered in large doses, and within five weeks a marked amelioration took place. The aphasia had greatly improved, and instead of the choreic movements of the whole arm there were only continual, slow, grasping movements of the fingers. In other words, the hemichorea had subsided into athetosis.

Three years afterwards, Bernhardt saw and examined the patient, and found her condition substantially the same. There was still athetosis and right hemianopsia. The patient continued to drag the right leg a little, and the symptoms of aphasia had not altogether disappeared.

Binswanger on Secondary Degenerations after Lesions of the Cortical Motor Centres.—Binswanger (*Archiv f. Psych.* Bd. xi. p. 727) reports the following cases to show that lesions of the motor portion of the cortex cerebri or of the adjacent portions of the medulla do not always cause secondary degenerations of the pyramidal strands. In each of the cases the basal ganglia and the internal capsule were found intact, and there was no trace of secondary degeneration of the pyramidal tracts either in the spinal cord or the brain.

(1) A man, aged 48, was seized in March, 1880, with an attack of convulsions. He had another attack in a month, and subsequently the convulsions returned about every ten days. They began in the right hand. In September he had three fits in one day. After this he had no more fits, but a weakness, first of the right arm, then of the face and leg, became noticeable, and gradually increased in degree, until, in November, there was complete right hemiplegia and aphasia. The sensibility of the paralysed limbs was carefully examined, and found intact. The man died on November 25. The *post mortem* showed a small focus of softening at the place of junction of the second frontal convolution with the ascending frontal, and the adjacent part of the upper third of the ascending frontal convolution was soft and pulpy and of greyish-yellow colour. Underneath this softened cortex was a cavity, as large as a walnut, full of clear brown fluid, which was separated from the outer capsule and the roof of the lateral ventricle by a narrow strip of healthy medulla.

(2) A woman, aged 56, who had suffered for some months from headache and vertigo, and had had a slight and transient paralytic attack on the left side, was shortly afterwards seized with a second attack, and died in a few weeks. In this second attack there was complete paralysis of the left face and arm, and partial paralysis of the left leg. *Post-mortem:* the posterior parts of the superior and middle frontal convolutions, and the upper third of the ascending frontal convolution were found occupied by a tumour about the size of a hen's egg; and the cortex here was of abnormally dense consistence. In the medulla, outside the corpus striatum, and somewhat more anteriorly than the first tumour, was a second larger tumour, which was bounded superficially and deeply by a layer of softened brain substance.

(3) A woman, aged 50, who was operated on in April for carcinoma of the breast, soon afterwards had an attack of convulsions which affected the right arm and face, and was followed by

paralysis of the right arm and face and by some aphasic symptoms. The hemiplegia became completed before death. The patient died on June 25, and at the autopsy a tumour, almost as large as a hen's egg, was found imbedded in the middle of the fissure of Rolando. The surrounding brain-substance was softened and discoloured.

Binswanger does not attempt to explain how it is that in some cases of lesion of the motor region there is, and in other cases is not, secondary degeneration of the pyramidal tracts.

W. J. Dodds, D.Sc.

Rumpf on the Treatment of Locomotor Ataxia with the Electric Brush. (*Neurolog. Centralblatt*, 1882, Nos. 1 and 2.)—The results obtained by the author are so striking that we should have felt incredulous had not they been related with full details by so competent an authority as Dr. Rumpf.

The first case was that of a man who, ten years before, had been attacked with the characteristic shooting pains. The usual symptoms manifested themselves in the course of time: extreme ataxia, anæsthesia and analgesia, abolition of reflexes, sense of fatigue, bladder disturbance, sleeplessness, &c. The electric brush was used along the back and legs, and very soon this brought about a considerable amelioration of the subjective symptoms, and the treatment persevered in for two months, when the patient declared himself prepared to resume his work. One year after this, Dr. Rumpf had the opportunity of showing him to the members of the Medical Society of Düsseldorf. The only symptom then present was the absence of the knee-jerk.

Dr. Rumpf stated that he had tried the brush in a series of cases successfully, though the results require time before they can be pronounced permanent. He described one, however, in which the patient had been in good condition for two years after a six weeks' course of treatment. He had had lightning pains, paræsthesiæ and ataxia, impotence and disturbed micturition. The knee-jerk was not abolished. All the symptoms disappeared except the sexual weakness.

Eulenburg on the Latency of the so-called "Tendon Reflex." (*Zeitschrift für Klinische Medicin*, i. 1882.)—The author has measured the latency of the knee-jerk on more than 100 healthy individuals, and finds it to vary between ·0016 and ·032 of a second. These numbers are much smaller than those hitherto given. He calculates that the time necessary for a reflex

act would be longer than ·03, hence concludes to the direct action of the stimulus on the muscular fibres.

Friedreich on Paramyoclonus multiplex. (*Virchow's Archiv*, vol. 86, No. 3.)—Prof. Friedreich relates the case of a man, aged 50, who shortly after a great fright, five years ago, became subject to curious symmetrical clonic spasms in a number of muscles (arms and legs). When quiet the number of jerks amounted from ten to twenty, when excited, to forty or fifty, a minute. During sleep he was free from them, and voluntary movements brought them to a standstill. Except an increase in the skin reflexes and in the knee-jerks, he presented no abnormal phenomena. Galvanism was successfully applied. The author explains the symptoms by assuming an abnormal irritability of certain groups of motor cells in the anterior horns.

Lannois on a case of Paralysis of the Brachial Plexus. (*Revue de Médecine*, 1881, p. 988.)—The author gives a case which is a counterpart of those first described by Erb, and in which, owing to disease of the fifth and sixth cervical roots there is paralysis and atrophy, of the scapular muscles, deltoid, biceps, and supination. In the subject of this observation all the muscles of the hand and forearm, except the supinators, were affected. Sensation was correspondingly impaired. This points to an affection of the cord formed by the seventh and eighth cervical and first dorsal roots. (Cf. 'Brain,' Vol. II., p. 584.)

Charcot on the Galvanisation of the Brain of Hypnotised Hysterical Patients. (*Progrès Médical*, 1882, Nos. 2 and 4.)—Prof. Charcot relates some curious experiments showing that the cerebral centres apparently share in the general hyperexcitability observed in certain hypnotised subjects. Makes and breaks, more especially voltaic alternatives, of a current from four to ten Leclanché cells applied to one hemisphere, gave rise in several cases to muscular contractions on the opposite side of the body. In the waking condition no such effects were ever produced. In other patients the muscular contractions occurred on the same side of the body. Finally, in cases where peripheral hyperexcitability was not well marked, the effects of cerebral galvanisation were but slight. Prof. Charcot expresses himself with great reserve on this subject, which is full of interest, but this requires much careful investigation.

Müller and Ebner on Nerve Stretching. (*Wiener Klinik*, vii. 1881.)—This paper contains a full account of all that had been published up to date with reference to nerve-stretching and its results. The authors then describe very minutely two cases in which the operation relieved the ataxy and anæsthesia, and removed agonising pains to which the patients had been subject 22 and 14 years respectively. They do not, however, look upon the remedy as more than a symptomatic mode of treatment, with (probably) temporary effects only. Nevertheless, with these restrictions its results are often very striking, and unapproached by those of any other therapeutic measure.

They discuss the explanations hitherto given of the "modus agendi" of nerve-stretching, and take the view that it acts less by its coarse anatomical than by its finer molecular effects, which spread to the nerve endings and spinal centres. The experiments of Brown-Séquard on animals, repeated by Scheving, Debove, Quinquaud and others, prove an alteration in the spinal functions consecutive on stretching the sciatic.

The result of nerve-stretching in affections of the sensibility will depend less upon the character of the symptoms (paralgesia, anæsthesia, neuralgia, etc.) than upon the possibility of influencing the spot of the irritative lesion by means of the mechanical stimulus. Hence the doubtful value of the operation when the seat of morbid action is in the brain. In cases of motor hyperexcitability, it is indicated when the lesion is spinal (facial and accessory spasm, dissemitrated sclerosis, late rigidity, etc.). It is useless in paralysis agitans, athetosis, and the like. In traumatic tetanus it ought to be resorted to without delay. It may be of use in certain trophoneuroses.

Gowers on a Case of Loss of Taste from Disease of the Fifth Nerve. (*Journal of Physiology*, vol. iii. p. 229.)—A female, aged 32, after certain premonitory symptoms was seized with sudden anæsthesia and paralysis of the parts innervated by the right trigeminus. No history of syphilis. It was found that on the whole right side of the tongue the sense of taste had disappeared. The lesion probably involved the fifth nerve near the pons; and though the glosso-pharyngeal nerve was intact, yet the nerve of taste had disappeared from those regions usually believed to be innervated by it. The author concludes that in this patient all the gustatory fibres arose from the fifth nerve.

Erb on the Course of the Gustatory Fibres of the Chorda

Tympani to the Brain. (*Neurolog. Centralblatt*, 1882–4.)—The author relates a case which seems to settle this still doubtful point. There was (1) Abolition of the sense of taste on the anterior two-thirds of the tongue on the right side. (2) Integrity of the facial nerve. (3) Lesion of the whole fifth nerve at the base of the skull. This concomitance of symptoms indicates that the gustatory fibres of the chorda tympani reach the brain through the trunk of the trigeminus.

More lately still, Erb has had the opportunity of observing two cases of disease of the fifth nerve. (*Neur. Centralbl.* No. 5.) In the first there was hypæsthesia on the left side; but no paralysis, nor disturbance of the hearing. The sense of taste was considerably diminished on the interior left half of the tongue. In the second there was paralysis of the muscles of mastication on the right side, with complete anæsthesia of the parts innervated by the third branch of the fifth.

Prof. Erb concludes that the gustatory fibres of the chorda tympani run into the second branch of the fifth.

A. DE WATTEVILLE.

N. Bubnoff and R. Heidenhain on Phenomena of Excitation and Inhibition in the Cerebral Motor Centres. (*Pflüger's Archiv*, vol. xxvi. p. 137.)—The above paper contains in the first place observations confirmatory of those of Franck and Pitres on the reaction-time of the cerebral grey matter to electrical stimuli (Trav. du Lab. de M. Marey, 1878–1879, p. 413); it further gives an account of the experimental determination of certain excitatory and inhibitory cerebral effects as indicated by simple spasm, storm of spasms or continuous contraction, or by the arrest of these states.

Franck and Pitres found that the reaction-time is considerably longer when excitation is applied to the grey substance, than when it is applied to the subcortical white substance (e.g. 0·065 sec. in the former case, 0·045 sec. in the latter). Bubnoff and Heidenhain confirm this fact. They find that the muscle-curve obtained by cortical excitation has a longer latency and a greater duration than that obtained by medullary excitation (e.g. the latency in the former case being 0·08 sec., in the latter 0·035 sec.); they observe further that the length of the interval varies inversely with the strength of excitation. All these observations go to show that time is occupied by the excitatory process in the cortex, and contradict the opinion that the grey matter is physiologically in-

different. The authors, however, observed that in the stage of increased excitability as an effect of morphinisation, the reaction-time of cortical stimulation may be as low as 0·02 to 0·025 sec.; the total delay of mere nerve transmission and muscle latency would amount to this, leaving a by no means evident cortical delay. They also observed great prolongation of the cortical reaction-time in deep morphinisation, a prolongation which was at once greatly diminished by substituting subcortical for cortical excitation.

With regard to the experimental determination of action and resolution of action, several significant observations are related.

Munk observed that epileptic convulsions brought about by excitation of a limited cortical area can be abolished by removal of that part of the cortex, unless the convulsions have lasted for some time, in which case extirpation fails to effect quiescence. Bubnoff and Heidenhain observe further that sometimes in the early period of an epileptic attack, extirpation of the cortical centre of a limb may effect quiescence of that limb while the rest of the body remains in strong convulsion; they suppose that the excitatory state has now extended to the whole cortex, but has not yet established itself in subcortical matter. In other cases, after rapid destruction of the motor area on one side, they observed cessation of convulsion not only on the opposite side but on both sides, it being indifferent whether the area removed were the same as, or the opposite to, that by which the outbreak was originally excited; —they suppose that each motor area not only governs the opposite muscles, but that each area also influences the opposite area, and that failing this excitatory factor the excitation soon becomes insufficient to convulse. In other cases they observed that unilateral ablation had no effect on the convulsions; they suppose that the excitatory state had then extended to subcortical motor apparatus. The authors remark also that epilepsy by excitation of the cortex on one side, always commences by muscles on the opposite side; that epilepsy by excitation of subcortical matter (the cortex of that side having been removed) always commences on the same side, and that after bilateral ablation of the cortex, subcortical excitation is never succeeded by an epileptic attack. Admitting the facts, the deductions from them are obvious—experimental epilepsy is a manifestation of cortical activity, which crosses to the opposite side of the brain by commissural fibres.

Turning to other sides of the question, the authors show how centripetal impressions can influence central excitability, e.g. on the one hand, that the muscle-curve of cortical excitation may be

retarded and prolonged by simultaneous excitation of the sciatic; on the other, that submaximal cortical stimulation may be rendered efficient by gentle tactile excitation on the same side. The results depend greatly upon the depth of morphinisation, and it must be added that the latter phenomenon occurs also after removal of the cortex; the enhanced excitability is therefore certainly of subcortical parts, and only *possibly* of cortical substance.

Other phenomena are recorded of a precisely opposite character, viz. the resolution of tonic contraction by gentle tactile excitation, by sudden sounds or blows, or by weak excitation of the sciatic; but here again the part played by cortical matter is not clearly defined, since the phenomena were exceptionally observed in its absence, and could then only depend on subcortical processes.

The authors also observed arrest of action by weak central excitation, increase of action by stronger central excitation applied to the same cortical parts as those from which the observed action proceeded as well as to remote parts.

For the discussion of imaginable representations of the dynamic changes effecting action and resolution of action, the reader is referred to the original paper, in which they are considered at length.

Prof. Christian Loven on the Tone of Muscles excited electrically, and certain Electro-acoustical Phenomena connected with it (with an original Note). (*Arch. für Anat. u. Physiol.* (*Phys. Abth.*) 1881. Heft v. p. 363.)—According to Haughton, the sound of strong voluntary contraction indicates 30–36 vibrations per second.

According to Helmholtz it indicates 36–40, but by consonating strings he concluded that the real vibration-frequency is an octave lower (18 to 20).

Loven affirms that the v.-f. is half this, viz. 9 to 10 per sec., seeing that the spasm frequency of strychnia clonus is about that number (v. Nordiskt Med. Ark. 1879, No. 14). The minimum number of stimuli necessary to cause complete tetanus varies; Loven says that for mammalia generally it is between 20 and 30 per sec.

Listening to the muscle-tone elicited by high interruption frequency, Loven was surprised to notice that the tone heard over the muscle itself is just as well heard in any other part of the body. It was clear that this tone depends on something else than muscle vibration, especially as the observation can be made on dead animals. He first thought of unipolar charging, but he observed that the

tone is well heard when animal and observer are completely insulated.

Seeking to determine the conditions of this electro-acoustic phenomenon, he found it necessary that the *animal and observer should be separated by a moderately thick non-conductor.* The sound is at its loudest when, with one pole on the animal, the ear of the observer is applied thereto; if now a stethoscope is substituted, no sound is heard, provided no part of the observer is near to or touching the dry hairy skin; nor is any sound heard if the observer should happen to touch a wound or the wetted skin of the animal.

Given the above condition, the experiment may be more simply improvised. A wet sponge covered with indiarubber sheeting represents the animal, and is joined to one pole of the coil; the other pole being brought to earth or not (in the former case the sound is rather better). On touching one's ear with the former, one feels at the first light touch a weak pricking and a crackling sound, and on firmer pressure all the peculiarities of the interruption.

The fact may be made evident in several ways: 1. When one holds one pole of a coil, the head being covered by a sheet of thin indiarubber, nothing is felt or heard; but if a second person places his ear against the sheeting the sound is heard by both, and so on for a string of people, providing they be not in conducting chain. The sound is strongest if each terminal person is joined to the coil.

2. One pole is joined to a sheet of metal. On touching the metal, especially if firmly with the moist finger, nothing is felt or heard; if now one covers the metal with indiarubber sheeting (or better, if one superposes on this sheeting a second metal-plate), and touches with the wet finger, sound is heard, most distinctly if the second metal-plate is joined to the other pole of the coil. If the single plate is lightly touched or stroked with the dry finger, one feels as if the plate were rough, though it be quite smooth, and sound is heard; it is best, but not essential, to connect oneself with the earth.

These phenomena evidently depend on static electricity, since an insulating partition is necessary.

At the free pole (i.e. that connected with the sponge or with the metal plate), there is, at a given instant, positive electricity of high tension, at a succeeding instant negative electricity, with each make and break of the primary circuit. If now to this a conductor

is approached, but separated by a thin insulating partition, opposite electric tension is induced by influence, viz., + when the pole is −; − when the pole is +.

The tone may be attributed to (1) actual charging on each side of the insulator, or (2) to molecular vibration in the conductors by the sudden reversal of electrical tension, or (3) to molecular vibration of the insulator, in consequence of the induction action.

Loven inclines to the first of these explanations, and relates this experiment. Two metal plates, ½ cm. distant, joined to two poles of secondary coil, give no sound. A frame on which india-rubber, or, better, gutta-percha paper is stretched, being introduced between the metal plates, a loud sound is heard, when the plates are separated as much as 30 cm. The sound can also be heard with but one metal plate, also when the observer holds one pole and brings the gutta percha close to his ear, and when the sound is absent it can be brought out by electrifying the sheeting by rubbing with the hand.

It might be asked how these facts disclose any source of error in acoustic experiments on muscle, since they are produced in an open circuit with strong currents; but Loven states that he has brought out the phenomenon when the circuit was closed through a short bit of nerve or wet thread.

What small tension differences are sufficient comes out in the following experiments:

1. Both poles are brought to binding-screws a few centimetres apart, joined by a moist thread. A second thread is fixed to the first by a slider, so that it can be pushed along the former, and its other end is joined to a metal plate, or covered sponge. If the slider is near one of the screws, the sound is loud; if it is gradually pushed towards the middle, the sound becomes weaker; when quite in the middle, sound of course vanishes; but it can be faintly heard when the slider is only a few mm. from the middle.

2. When the poles of a coil are joined to a second coil of fine wire, through which the current must therefore pass, and the ear is placed on the latter, sound is heard. That it does not, or at least can only slightly depend on molecular vibrations, is shown by the greater sound heard on a covered sponge or metal plate connected with one screw of the second coil.

That the high tension at the poles of this coil does not depend upon its resistance is shown by the substitution of a rheostat of higher resistance, which brings out no trace of sound. The phenomenon is doubtlessly due to extra-currents generated in the

coil, and which render the latter, in virtue of this fact, comparable with a bad conductor, such as a nerve or a moist thread.

These experiments seem to show that the phenomenon may occur under the ordinary conditions of myophonic experiments. It is specially liable to happen if the currents are strong, if the electrode contact is anywise deficient, if the electrode interval is over 2 to 3 mm. *The way to guard against it is to establish a good conductor between animal and observer.*

Professor Loven relates further the following experiments on the muscle-tone. On frogs he could hear no sound with a Hughes's microphone, when he excited indirectly; with rather strong currents and by direct excitation he heard a sound, but which continued unaltered after complete exhaustion and death of the muscle, or with substitution of WET thread for the muscle. The sound, therefore, depends on vibrations, the immediate consequence of induction. On rabbits, by indirect excitation (sciatic), using an interrupter resembling Bernstein's acoustic interrupter, he examined the questions (1) How far strength of current influences the muscle-sound; and (2) What is the greatest vibration-frequency with which it continues to agree? To the second question, Bernstein's experiments and those of Kronecker and Stirling appear to answer that there is no limit. The first question is hitherto untouched.

Using the coil without its core, and at the max. distance giving complete tetanus, he was surprised to find that a sound was heard at once with its max. loudness, and that on increasing the strength of the current the sound grew weaker till it vanished, "leaving only the ordinary muscle-sound." With moderately high vibration-frequency, 330–380 per sec., and weak excitation, the tone was distinctly an octave lower than the interrupter-note. Often (but only when the vibration-freq. was not too great), after the sound had vanished with increased strength, it reappeared, but in unison; if now the original strength were returned to, the lower octave was heard.

To test the alteration of sound with alteration of stimulus-frequency used, the voice sang into a telephone from g to g′ (198 to 396). The muscle-scale was heard up to C′ (264), d′ was indistinct, e′, fis′, g′ distinct, but belonging to the lower octave.

Exciting by the telephone and whistles, he got no sounds with a stimulus-frequency above 800 per sec., although there was strong muscular tetanus.

According to Bernstein, Kronecker, and Stirling, not only the

pitch but also the quality of the muscle-sound corresponds with that of the interrupter. Loven contradicts this statement, and says the sound has no clang, does not differ whether the contraction were excited by a man's voice or by a whistle acting on the telephone; it only gave the ground-tone or under-tone, never the *over-tone*.

Loven remarks on the peculiarity that it is only in the weaker strin. that the lower octave is heard, and believes it to be a *physiological* phenomenon. Bernstein stated that the muscle-tone becomes weaker when the interruption-frequency passes 300 to 400, and brings this in relation with the duration of the neg. var. Loven never succeeded in observing a distinct decline in the muscle-tone in passing any given stimulation-frequency. He states that its intensity depends, above all, on the strength of stimulation.

Note by Reporter.

The commonly received doctrine, based on the authority of Helmholtz, is that voluntary tetanus is compounded by 18 to 20 discharges per sec. from the spinal cord. Loven, basing his opinion on the fact that of strychninised frogs the spinal clonus initiated by any peripheral stimulus has a rhythm of 8 to 10 per sec., thinks that voluntary tetanus is compounded by 9 to 10 stimuli per sec. viz., by a frequency ½ that of the vibrations of the note heard, and ½ that given by Helmholtz. It has been generally asserted that 18 to 20 induction shocks per sec. give complete tetanus on man, and Prof. Loven states that on mammalia complete tetanus is reached with 20 to 30 interruptions per sec. In relation to this question, I observe that the maximum number of voluntary contractions corresponds with the figure given by Prof. Loven, being generally 8 to 10 per sec.; also that the rhythm of morbid spasms—trepidation, clonus, tremor—is about the same, viz. 8 to 10 per sec. ('BRAIN,' July, 1880, p. 179). I do not find the strychnine clonus in the frog to be constant spasm-frequency, the rhythm usually becoming slower with fatigue, and I have now under my eyes a tracing showing a vibration-frequency of only 5 per sec. On the other hand, I observe on my own muscles incomplete tetanic fusion, with an interruption frequency of over 50 per sec.; whereas voluntary tetanus (if it be tetanus) gives an unbroken line. This observation is opposed to the current theory of the composition of voluntary tetanus by 18 to 20 spinal discharges per sec. A. WALLER.